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Applied Science

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TRANSACTIONS OF THE UNIVERSITY OF TORONTO ENGINEERING SOCIETY

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STEREOGRAPHIC MEASUREMENT.

By G. R. Anderson, M.A.
Associate Professor of Photography, University of Toronto.

The problem of deducing measurements from a photograph is the inverse of that of producing a perspective drawing from the known dimensions of an object, for the image produced by the lens on a photographic plate is a true perspective if the lens be free from spherical aberration and astigmatism.

If the plate be assumed vertical then the nodal point of the lens is the point of view, the plate is the picture plane, and the focal length of the lens is the distance line. The optic axis of the lens intersects the plate in the principal point and a horizontal line drawn through this point is the horizon of the perspective. Having given the horizon line of a photograph the principal point and the distance line, that is the focal length of the lens, the problem of estimating the object in all its parts is, however, indeterminate, for we have two unknown quantities, viz., the distance of the object and its dimensions, which are dependent on each other. But if we are provided with two perspectives of the same object from suitable stations, the problem may be solved by plane table methods.

The use of photographs in surveying dates back as far as 1858 or 1859, about which time Colonel Laussedat executed numerous experimental surveys with the camera, the results of which were communicated to the Academy of Sciences and received the endorsation of that body. Subsequently the method was taken up by Meydenbaur in Germany, and was used to some extent in military work during the Franco-German war, later it was exploited by Finsterwalder, Koppe, and others. It was also used in Austria, Sweden, Switzerland and Italy during the seventies and eighties. Perhaps the most extensive work by the photographic method was in the Rocky Mountain survey and the Alaska boundary delimitation (Canadian section) under Deville, Surveyor-General of Dominion Lands; this work was begun in 1888 and continued up to about 1897, and was most successful.

In all this work extending over a period of 30 or 40 years, the methods employed for reduction of the photographs, though differing much in detail, were all what may be fitly termed "monocular"; that is to say, a single photograph was in itself a unit and the determination of any magnitude was arrived at by the comparison of two or more units. The various methods are all somewhat intricate and laborious, and, moreover, the identification of terrestrial details as viewed from two or more stations at different angles is often very difficult. Again, the method is not self-contained, for the camera stations and other control points must be determined by triangulation or other extraneous method.

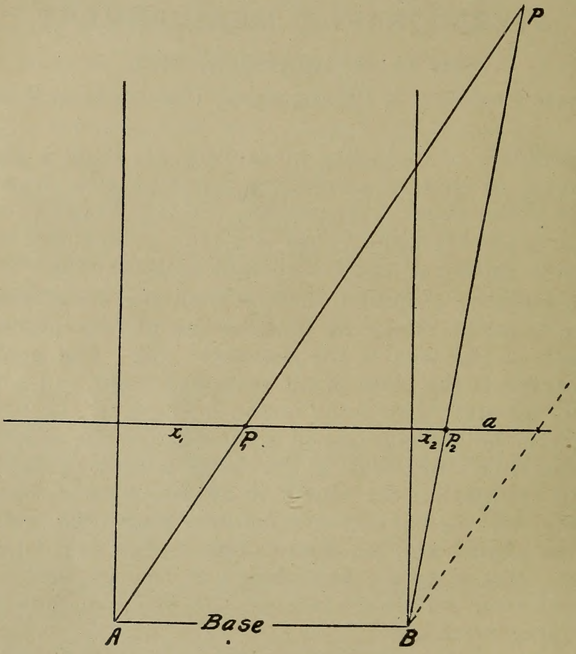

Fig. 1.

This plan of taking a single photograph as a unit is analagous to that of a man who views an object with one eye closed and then moves to a new view point and makes a similar observation, instead of using both eyes from one station. It seems all the more remarkable that the binocular method was not introduced when the plastic properties of a stereograph were so well known, for the invention of the stereoscope dates back to 1838.

The first suggestion of utilizing stereoscopic photographs for measurement of distance by means of a comparator seems to have been made by Dr. Pulfrich of the scientific staff of the Zeiss works, in 1901. (See "Naturwissenschaftliche Rundschau," 16, page 589.) From that time on numerous articles have appeared in scientific periodicals dealing with the problem, and meantime the firm of Carl Zeiss has steadily improved the original apparatus until a permanent form of both camera and comparator have now been reached, both of which are of great perfection.

In this paper I purpose to deal with the question of measurement only, assuming that means have been used to secure accuracy in the setting of the camera.

Consider a single photograph and let lines be drawn on it representing the horizon and principal line of the picture. This will divide the photograph into quadrants and the co-ordinates x and y of any point therein may be measured by means of a comparator. The actual values of these quantities cannot, however, be determined until their distances from the station are measured and this distance may be obtained from a stereoscopic pair.

The method of measuring the depth of field to any point from a stereograph requires a linear measurement of the parallax of that point. The relation between parallax and depth of field may be illustrated by the accompanying diagram, Fig. 1.

Let A and B be the two points of observation, and let P_1 and P_2 be the images of the distant point P on the picture plane, then x_1 is the ordinate of left image, and x_2 of the right and the difference between AB and P_1 P_2 is the parallax and is obviously equal to $x_1 - x_2$. Let the parallax be denoted by a, equal to the algebraic difference of the ordinates. It is clear that when the parallax a equals O the point P must be at infinity, and that ^{h} increases as P approaches AB, also that all points lying on a vertical plane through P parallel to AB have the same parallax.

Fig. 2 exhibits the parallax of various points in an actual stereograph. The base of the pair of photographs was 2.438 m. and the focal length of the lens was 141 mm. As the picture is mounted the base is represented by a distance of 145 mm., and the distances between various pairs of points are shown on the figure, from which it is seen that the nearer the points lie to the station the greater the parallax. It must be observed, of course, that the parallax is not a measure of the distance directly to the distant point, but a measure of the perpendicular distance between two vertical planes, one of which passes through the station points and the other through the distant point parallel to the first, in other words, the "Z" of a rectangular system of co-ordinates.

In the taking of the photographs it is necessary that the plates be vertical and that they lie in one plane; the stations may be on the same or different levels. The length of the base and the focal length of the lens are required. By convention the left station may be conveniently taken as the point from which

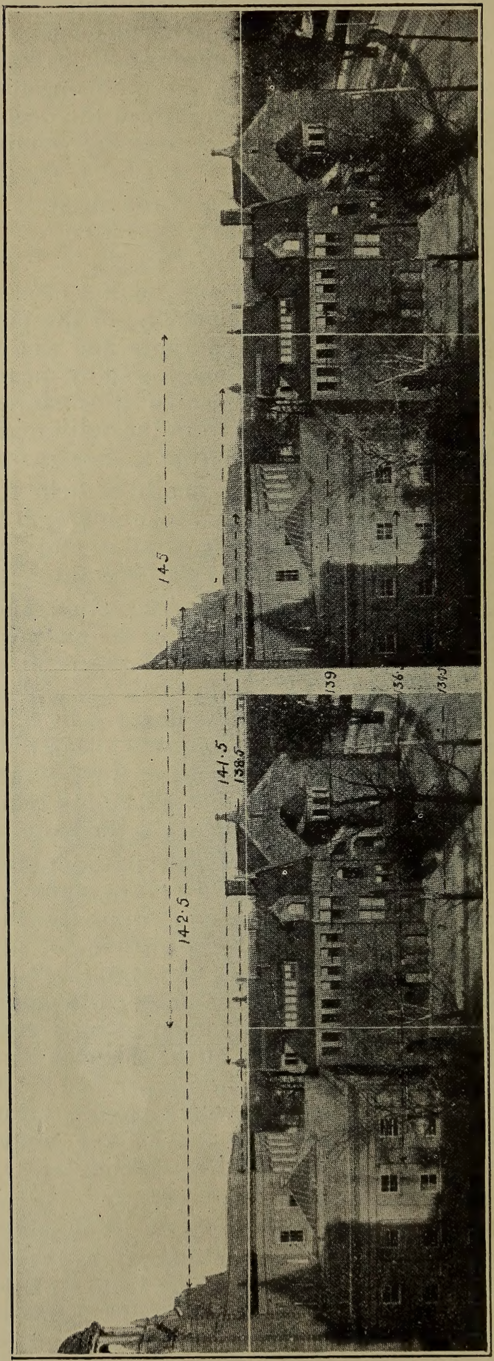

Fig. 2—Base = 2.438 metres, f = 141 mm.

measurements are to be made, hence the co-ordinates x and y will be measured from the left plate and the parallax from both.

It now remains to show how the actual co-ordinates of a point in space may be determined from the co-ordinates as measured on the stereograph. In Fig. 3:

Let P be the point whose position is to be determined, and which is represented on the plates by the images P_1 and P_2; let the ordinates of these points be x and x^1, (x^1 being negative), let B be the base and f the focal length of the lens. Then, from similar triangles it is evident that Z, the distance of a plane through $P = B\frac{f}{x + x^1}, = B\frac{f}{a}$

also $X = Z\frac{x}{f}$ and $Y = Z\frac{y}{f}$

Fig. 4 shows the latest model of the stereo-comparator destined for the precise measurement of stereographs, one of which

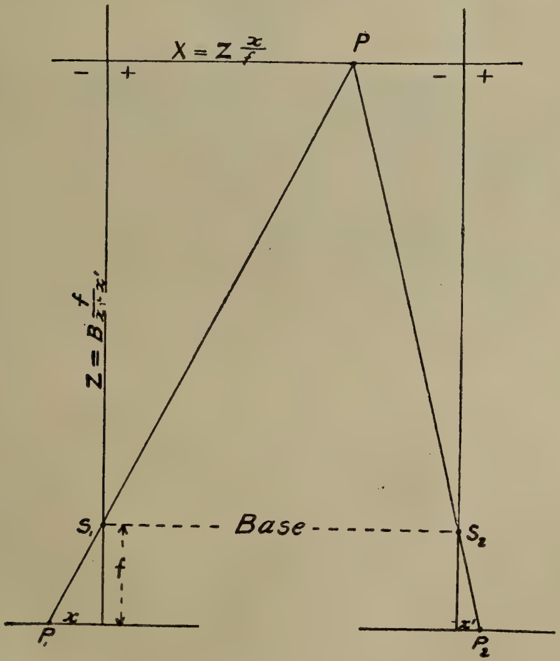

Fig. 3

has lately been added to the photographic equipment in the University of Toronto. The instrument is provided with a binocular microscope magnifying eight times, of which the objectives are shown by O_1 and O_2, the eye pieces by E_1 and E_2. The microscope may be focussed on the plates by a screw not visible in the figure, and the eye pieces may be separately adjusted to compensate differences in the eyes of the observer and are also adjustable to different interocular distances.

The plates P_1 and P_2 are rigidly held in place by metal clamps, and are illuminated from beneath by adjustable mirrors M_1 and M_2. Each plate may be rotated in its own plane by screws S_1 and S_2, so that the horizons of the two plates may be accurately adjusted. Also, the right plate P_2 may be moved parallel to its length by the screw H so as to compensate for difference in level of the two stations. In the optical planes of the microscope are two balloon marks which appear to coincide when the instrument is in accurate adjustment, and may be set so as to apparently coincide with any point on the stereograph whose position is required.

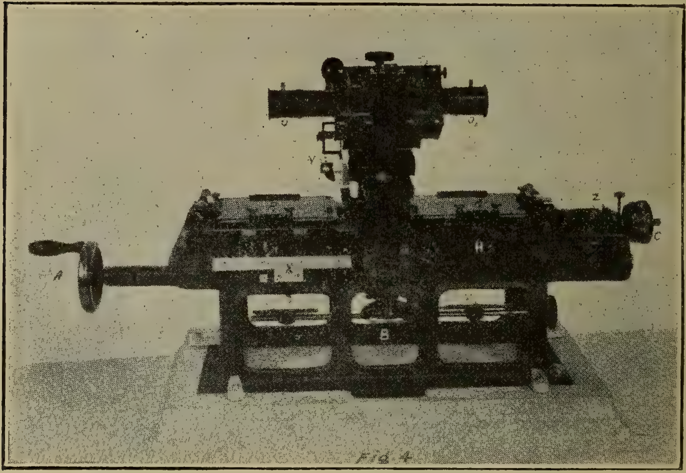

Fig. 4.

The screw A moves the entire bed plate, carrying both plates to the right or left, and its movement is indicated on the scale X, the screw B moves the microscope at right angles to the bed plate, and its motion is indicated in the scale Y, and the screw C moves the right plate to the right or left independently of the other plate, and its movement is indicated by a scale and divided screw head Z. All three scales read to 1/50 mm., and by estimation to 1/100 mm. Thus, by means of the scale X the distance of any point to left (+) or right (—) of the optic axis is measured by means of *Y* the height of any point above (+) or its depth below (—) the horizon is measured, and lastly, by means of *Z* the parallax of any point is determined. From these three measurements made on the photographs the actual co-ordinates in space are at once determined by means of the simple formulas already given.

The great simplicity of this method as compared to that of plotting by means of the plane table will be at once apparent, and the precision secured is much superior and comparable to that of any other method of survey in ordinary country, while in mountainous districts it ensures results that cannot otherwise be secured except at very great cost.

The application of photogrammetry to stereographs is not confined to survey work alone, but may be used for any purpose where measurement is required. For example, if two cameras are used and simultaneous exposures are made the method becomes applicable to moving objects, and may be employed to indicate the position at any instant of military forces during manoeuvres in the field or of vessels at sea, or to determine the altitude of clouds, aeroplanes or the flights of birds. In a similar way the method becomes readily applicable in astronomy. In architecture it may be employed to examine and measure details which are not readily accessible. Again, the method may be modified by taking two photographs from the same point at different times when any changes in the view will be at once made evident, this will find application in estimating relatively small changes, such as glacier motion, local variations in contour of the earth's surface, subsidence of structures, progress of earthworks, etc., or in the detection of spurious coins or counterfeit bank notes.

FOUNDRY IRON

By M. L. Smith, B.A.Sc., '11.

But little more than a decade ago this subject could have been considered in its entirety in a very few words. For centuries iron has been known and worked with little noticeable improvement in the methods employed, which was probably due to the fact that it was chiefly used for the making of fine steels.

The nineteenth century has been most appropriately named the "Iron Age," but it is more likely that the increased and more improved facilities for mining and handling have had more influence on its widespread adoption than has a knowledge of the metal itself.

The layman knew that it could be melted and that it would permanently retain the form of the mould into which it was poured and allowed to solidify. The founder knew, further, that certain combinations of pig and scrap made much better and stronger irons than others, that certain forms of castings would give way under shrinkage stresses, that gases were generated by the hot metal in the mould that must be provided for, and many other mechanical details which amounted to very nearly the extent of our present knowledge.

During the century it may be said that the methods of working evolved from the most primitive methods to those directed by the foreman governed entirely by rules of thumb and hearsay along with dearly bought experience.[1]

Then, with the coming of the twentieth century there sprang up with mushroom rapidity, a school of young technical metallurgists who, without foundry experience, came forth with the cry that chemical analysis was the only way to ensure success. Practical metallurgists of mature experience have found that, although chemical analysis is very important when considering problems in cast iron, it is only one of the agents to be taken into account, and "such is the nature of the metal that it is impossible to predict with certainty that positive physical results will follow a given analysis."

In fact, one of the greatest strides in conducting a foundry plant successfully has been the recognition by owners and managers of the value and importance of chemistry in connection with the mixing of iron and its intelligent use in conjunction with physical tests to obtain desired properties in castings.[2] With the aid of the chemist it is known what goes in; with his aid and by physical tests it is known what comes forth. The last and greatest step towards the gaining of combined physical and chemical knowledge however, has taken place within very recent years, assisted chiefly by the improved electric furnace, the introduction of the thermo couple by Le Chatelier, and the application of the microscope to the study of iron and steel, which first appeared in a paper by Sorby. Professor Turner also, in 1906, devised a simple instrument for correlating both volume and temperature of changes. So that the last five years have seen more investigation and research, as well as the production of more literature on the subject than has ever been seen before.

It may be said that the physical properties of the compound known as cast iron depend upon three things, viz.: the temperature to which it has been raised; rate of cooling, and chemical combination. The first two, in practice, depend more or less upon the last. Pure cast iron consists of iron and carbon which may be in the form of a graphite, or a carbide (Fe_3C). Compounds of over two per cent carbon are known as cast irons, all lower than this are classified among the steels.

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[1] "Native Iron and Coal Working in the Province of Shansi" China. *Engineering*, December, 1910, pp. 761.

[2] See R. H. Palmer, *American Machinist*, Vol. 25, pp. 1749.

The effect of the metalloids, viz., silicon, sulphur, manganese, and phosphorus, is nearly always indirect, and is in proportion to their effect on the condition of the carbon in the iron.

Silicon

The most generally accepted effect of silicon upon cast iron is that it causes the precipitation of graphite carbon by decomposing the carbides.

Charpy and Grenet had observed that the separation of graphite from originally white iron began at a temperature which was the lower the greater the percentage of associated silicon.[1]

The primary carbo-silicides are exceedingly unstable and are the first to decompose into graphite and silico-austenite. It is evidently the exceedingly unstable character of the silico carbide which is responsible for the greyness of commercial cast iron.

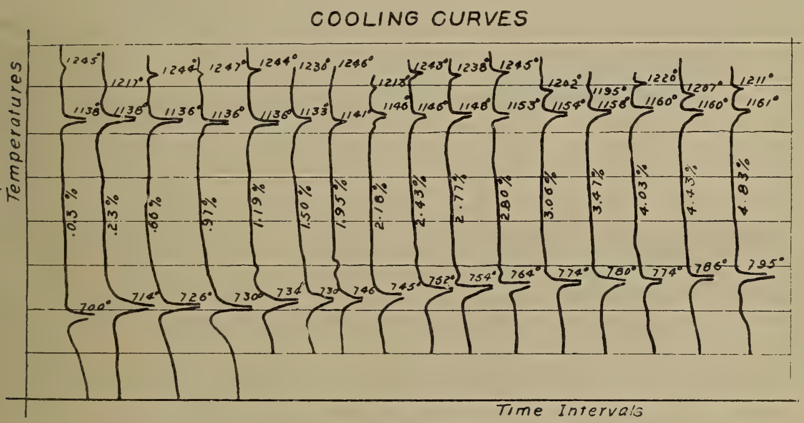

FIG. 1.

The effect of silicon upon the temperatures of solidification and recalescence are well shown by some extensive experiments of Mr. Arthur Hague, in which he designates the three arrest points by H_1 H_2 and H_3[2]. Some of his results are shown in Fig. 1.

The first arrest H_1, indicates the commencement of solidification. It is liable to inaccuracies and in some cases it is not definitely shown. The second arrest H_2, is a very definite one and indicates the solidification of eutectic. The third arrest, H_3, also a very definite one, corresponds to the recalescence or pearlitic point.

Turner showed that, in a pure white iron, there is no initial expansion but only a slight lag in the normal contraction. When a relatively small amount of silicon is present there is a distinct expansion at solidification, which occurs during H_1 and persists until the metal is solid or till the end of the eucectic arrest H_1. After the metal completely solidifies, it begins to contract, and the contraction is normal until the third arrest H_2,. when a more or less pronounced retardation in the contraction occurs. There is a more or less critical point between white and grey, and the greatest expansion seems to accompany the largest graphitic flakes, which occurs with a content of about 1% to 1.5% of silicon. After this percentage expansion is more or less constant but graphite flakes are more numerous and smaller. An increase of silicon lowers the temperature of the first arrest point H_1; raises H_2 slightly and raises H_3 very much. Thus the effect of silicon present as silico-ferrite or silico-cementite is to raise the temperature of the point at which carbide separates out, i.e., to increase the range of stability of alpha iron.

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[1] Thomas Kennedy, *Engineering*, July 22nd, 1910, pp. 140.

[2] Arthur, Hague, B.Sc., *Engineering*, Vol. 90, pp. 841.

The experiments of Professor T. Turner and A. Hague referred to in the above paragraph, corroborate generally the results of Mr. Hague[1]. Mr. Turner found that the effect of silicon is to raise the period from 700°C with no silicon to 750°C with 5 per cent silicon. The eutectic arrest showed very small but regular increase from 1130° to 1160° over the same range, while the temperature of the first arrest at the commencement of solidification was lowered.

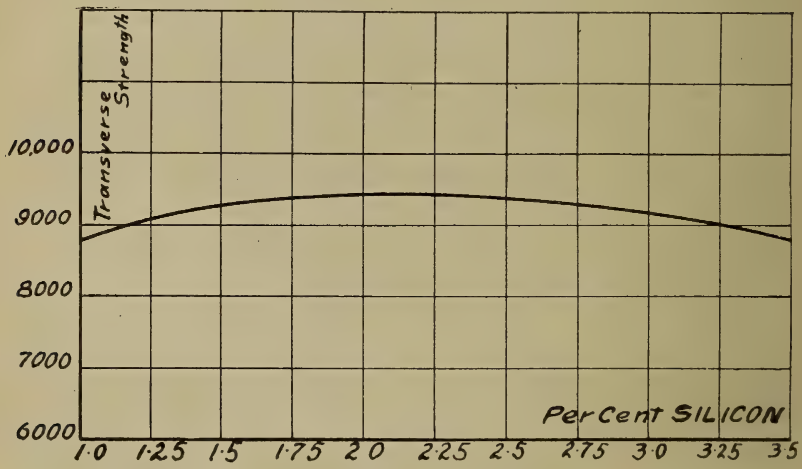

FIG. 2.

The strength of cast iron does not vary directly with its content of silicon, but nevertheless it seems to follow a continuous curve, as in Fig. 2. This graph, which is the result of many experiments, shows the strongest iron to contain about 2.1 per cent silicon, other elements being in average proportion.

The hardness of pure cast iron increases with additions of silicon up to 1% at which content it is still white. At this point it sudden-

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1. *Journal of Society of Chemical Industry*, 1910, pp. 1160.
2. Transactions of A. S. M. E., Vol. 25, pp. 914. W. J. Keep.

ly decreases after which it is more or less irregular. This is illustrated in Fig. 3.

The progressive influence of additions of silicon in softening iron and preventing carbon from remaining in the combined state decreases more or less rapidly as the silicon increases. The greatest effect is said by some writers to be with content of 1.5 to 2 per cent., but there is a difference of opinion on this point. It probably depends largely upon the amount and character of other elements present.

In general, the presence of silicon tends to accelerate the change from the meta stable carbide to the stable graphite condition. This results in the decomposing of the carbide at a lower temperature, which constantly causes the iron to be softer and greyer.

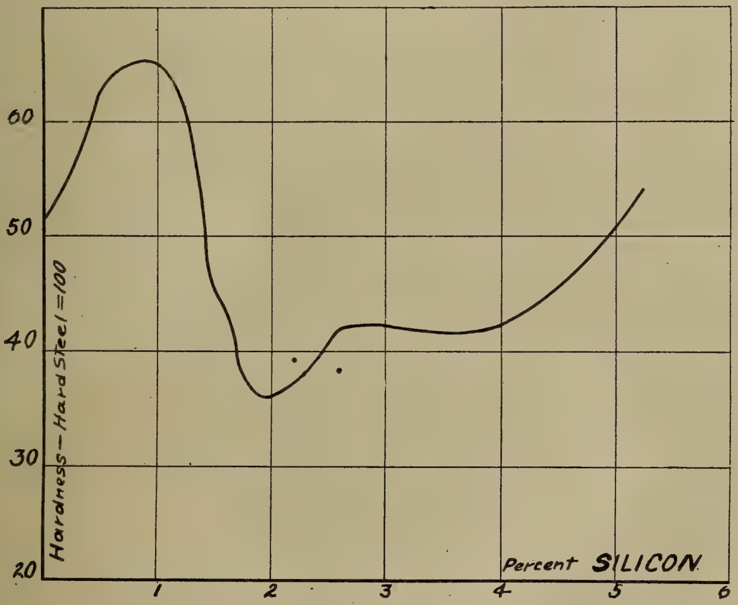

FIG. 3.

Sulphur

The presence of this element lowers the freezing point of the iron, at which temperature the Austenite, free from sulphur, is separated.[1] The sulphur at the same time is concentrated in an eutectic of austenite, cementite and a sulphide which solidifies at about 1130°C. In an iron free from sulphur the cementite decomposes with the formation of grey iron. The presence of sulphur, however, produces alternate layers of sulphide and cementite, the sulphide hindering the decomposition of the cementite (carbide), resulting in the production of a white iron. The pearlite point remains practically constant.

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[1] T. Liesching, *Journal of Society of Chemical Industry*, 1910, pp. 1207.

Practically, the results of sulphur are shown to be precisely opposite to those of silicon, the former having a hardening tendency by throwing the carbon into the combined state. Some attempts have been made to determine the amount of this effect for each fraction of a per cent. of sulphur, but little has been accomplished on account of the various effects of the presence of silicon, manganese and other conditions in different irons.

So far as is known to the writer, not one good word has been said for the element under discussion, and it is certain that all its evil effects are by no means realized. Its ultimate action has been very little investigated, but it is well known to all metallurgical chemists and others who have studied it that its immediate effect is to throw carbon into the combined form. It has, besides, an effect upon the grain of iron that is clearly visible and distinguishable at least in low silicon irons, and this is physically manifested in the weakness and rottenness of irons high in sulphur even when the castings are all grey.

It is in white irons, however, that the most striking difference occurs. The fractures of the two irons, one containing .03 per cent. sulphur and the other .06 per cent., are radically different even when the analysis is the same in all other respects.[1] One of the most objectionable features is the shrinkage it causes and the consequent contraction strains in high sulphur irons. These are best shown by white iron.

When a sample containing less than .04 or .05 per cent sulphur is cooled in water from a red heat, it does not make any sound, no matter if the iron is very low in silicon. An iron much higher in silicon and with .06 per cent. or over of sulphur, however, when cooled in the same way will almost invariably be heard to make a series of clicks as it cools by the formation of cracks generally nearly perpendicular to the length of the sample. These cracks go almost through so that the barest tap against a piece of wood will, in extreme cases break it in two.

The nature and appearance of the fracture of high sulphur iron is entirely different from that of low sulphur iron of the same analysis. In the former, it is entirely flat without any visible appearance of crystals and is quickly disclosed by a film of oxide, while the latter iron has beautiful crystals radiating from every cooling surface, especially from the bottom and the sides.

As the silicon content rises almost as great a difference continues to be noticeable, the low sulphur iron showing a "grain" or grey part at a much lower silicon content than the high. At the same time the high sulphur metal continues to show some white around the edges far beyond the silicon content at which the low sulphur iron had become all grey. The look of the grey part, too, is very different; that of high sulphur being fine grained and blue black as compared with the grey of the low sulphur which is much more open in grain.

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[1] J. E. Johnson, *American Machinist*, Vol. 26, pp. 1451.

When sulphur to the extent of about 2½ per cent. is melted with grey cast iron, a portion of the carbon separates in a sooty form and an intensely hard, white metal is produced. With a smaller quantity of 0.3 to 0.5 per cent a mottled iron of considerable strength is obtained, which, when broken, shows a quantity of grey spots enclosed in reticulating lines of white on the fractured surface.[1]

The natural deduction from the above is that, for chilled or white iron castings, foundrymen should not use an iron of moderately high silicon, say .7 per cent and get the desired chilling action by high sulphur of say 0.2 per cent. Instead they should use a low silicon iron if possible, say 0.2 per cent, and a moderate sulphur content (.06 or .07 per cent.) which would give an equal or better degree of chill as well as a casting of less shrinkage and far more available strength. This is particularly true of small and comparatively thin chilled castings. It is impossible, under ordinary conditions of working, to remove sulphur from the iron, but more can, to a great extent, be prevented from getting into it by careful working. Also, under certain conditions it reacts with manganese to form slag. These will, however, be discussed under the headings of "coke" and "manganese" respectively.

"Sulphur is bad, and there is no cure for its effects on castings except to keep it out of the pig and coke. Its effect is such that one point of sulphur will offset about fifteen points of silicon."

Phosphorus

The most generally recognized effect of phosphorus is to increase the fluidity of the iron. It may be used for very intricate castings up to 1 or 1.5 per cent with beneficial effects, but these are high values.

The action of phosphorus in lowering the melting point of iron is well established and it is probable that is the cause of its beneficial action on the fluidity and shrinkage.[2] It is obvious that if the metal stays melted at a lower temperature and the casting is fed from risers there will be a much shorter interval of temperature to traverse in cooling down to that of the atmosphere with corresponding reduced shrinkage. This, however, is by no means the only reason for these effects. The reason why such marked differences exist in shrinkage of phosphoric and sulphur irons has not been at all satisfactorily explained by any of the investigators whose writings are available to the writer of this article.

Phosphorus has been very thoroughly investigated by Mr. J. E. Stead in England and its effects in producing brittleness and unreliability have been clearly shown and reasons for the action discovered, but its effect of producing fluidity is so marked and its action in preventing shrinkage also, that, in cast iron, a metal well known to be brittle even when entirely free from phosphorus, the advantage up to a certain point far outweighs its disadvantages. Just where this point is for the general run of foundry work is hard to determine, but it is probably between 0.4 and 0.75 per cent.

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[1] Bauerman, *Iron and Coal Trades Review*, Vol. 77, pp. 278.

[2] J. E. Johnson, *American Machinist*, Vol. 26, pp. 1451.

Manganese

The character of this element and its effect upon cast iron has been much investigated by Mr. H. I. Coe and Mr. Stead.[1] The former found, in the case of white cast iron, the curve of expansion showed four minima, viz.:—

0% Mn, corresponding to the compound Fe C
5% Mn, corresponding to the compound 8 Fe C Mn$_3$C
15.3% Mn, corresponding to the compound 2 Fe C Mn$_3$C
19 % Mn, corresponding to the compound 3 Fe$_3$C $_2$ Mn$_3$C

Manganese appeared to lower the temperature at which the primary crystals separate out. The temperature of the eutectic arrest point is lowered by about 20°C for each one per cent. of Mn, but disappears at ten per cent Mn. Increase up to five per cent also lowers the pearlite point about the same amount. The pearlite becomes finer and more sorbic up to 5%. In the case of grey iron the expansion on solidification is very large. The temperature of solidification appears to rise with the addition of Mg. up to four per cent. Hardness increases up to two per cent, then falls to 2.65 per cent, after which it rises, first rapidly up to 4 per cent, and then uniformly.

The prevailing idea as to the effect of manganese on the condition of the carbon in cast iron is that it exerts an immediate whitening action and that three or four per cent will convert a grey iron into a perfectly white one. Keep, however, gives examples of iron rich in manganese being grey.[2] It has also been shown that the alloy with 8 per cent. of manganese may be definitely grey. Analysis show that although there may be, at first, a slight increase in carbide, the iron contains as much graphite relatively to combined carbon with 2.65 per cent manganese as with one per cent. Beyond this until 17 per cent. the quantity of combined carbon steadily increases. The cast alloy of 30 per cent. is perfectly white.[3]

Manganese increases the shrinkage by making the grain closer. The alloy with 11.15 per cent. has nearly twice the shrinkage as that of one per cent. Mr. Coe gives tables of many analyses to illustrate the progressive effects of manganese upon shrinkage and hardness, but space will not permit them to be cited here. Some crushing tests by Professor S. M. Dixon, of the University of Birmingham, however, are of interest.

THREE GREY IRON SAMPLES:

Bar	Mg.	Height	Thickness	Area	Load
B	1.00	1.25	0.633	0.395	37.34 tons
E	2.65	1.25	0.635	0.398	43.27 tons
F	3.45	1.25	0.638	0.404	46.91 tons

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1. H. I. Coe, *Journal of Chemical Industry*, 1910, pp. 1160.
2. *Cast Iron*, pp. 100, West.
3. H. I. Coe, *Engineering*, Vol. 90, 99, 581.

The increase of strength shown is more likely due to the effect of the element upon the grain of the iron than to its effect upon the carbon.

Manganese has a definite effect upon the sulphur content. Mr. Stead proves that sulphur crystallized with manganese as MnS previously to the solidification of the carbide, and that the metal then turned grey on cooling.

From the above, it is evident that manganese increases the expansion upon solidification, but in no definite ratio. The shrinkage increases with increase of manganese, but in no case is it as great as in white irons. It enables a very much larger proportion of carbon to be taken up and retained in the combined state. When free from manganese, cast iron contains little more than four per cent carbon in variable proportions of the graphitic and combined forms.[1]

Manganese up to one or two per cent. is not objectionable on account of any hardness that it gives the iron, and is much more likely to make it soft and prevent chilling of thin edges by its action on sulphur than it is to have the opposite effect on its own account.[2]

IRON MIXTURES

Analysis

The value of analysis cannot be overestimated, and a suitably quiet, clean, and convenient place should be provided for this, at the present time, very necessary department of the plant of any pretentions whatever. Several varieties of pig should be kept in stock and properly stored according to analysis, and analysis of scrap should be taken and recorded from time to time.

The writer does not propose to give the several standard methods used. They can easily be obtained from many excellent and complete text books on the subject, such as "Practical Methods for the Iron and Steel Works Chemist," by J. K. Heess, 1908, and others. It should be said, however, that much special apparatus is procurable that reduces ordinary analysis to very simple operations. For instance, in the case of combined carbon, the sample and a standard iron are dissolved in similar tubes, with equal amounts of dilute HNO_3. The amount of dilution necessary to bring the sample solution to the same color as the standard one gives the required percentage of carbon on the graduations of the tube. For accurate work the hydrogen jet method is recommended for sulphur.[3] A much improved method for general analysis has been devised by Messrs. C. H. & N. D. Risdale quite recently and provides very rapid methods for classes of work where variation is not great.[4]

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[1] H. Bauerman, *Metallurgy of Iron*, pp. 278.

[2] J. E. Johnson, *American Machinist*, Vol. 26, pp. 1451.

[3] Randolph Bolling, *Engineering News*, May 7, '08, pp. 505.

[4] C. H. & N. D. Risdale, before Iron and Steel Institute, *Engineering* June 16, 1911, pp. 801.

Samples should be taken by drilling several holes through the specimen. The drillings should be well mixed, and the required amount taken.

Mixing

To calculate the mixture three things must be known:—

(1) Analysis of pig and scrap.
(2) The changes that take place in the melting.
(3) The composition of the metal required.

Changes during melting depend upon,

(1) Construction of cupola.
(2) Pressure and volume of blast.
(3) Composition of coke.
(4) Grade of iron being melted.[1]

Ordinary grey iron containing two per cent and upwards of silicon will loose fron 0.2 to 0.3 per cent. silicon during melting. When there is less, the loss decreases and, with 1.5 per cent. there is practically none. Heavy blast will reduce graphitic carbon. Manganese tends to decrease it.

If sulphur is abnormally high, a greater loss of manganese is noticed, due to the formation of manganese sulphate. Sulphur generally increases from 0.2 to 0.38 per cent, except where very pure coke is used. Phosphorus remains practically constant.

Let it be required to find the percentage of silicon in a charge the weights of the irons being known.

Brand	Cwts. Used	Siliconpercent	Silicon Cwts.
A	3	4.00	12
B	4	2.25	9
Scrap	3	2.00	6
	10		27

Now 10 × silicon in mixture = 27

$$\text{then } \frac{27 \text{ (cwts. per cent.)}}{10} = 2.7 \text{ per cent silicon}$$

2.7 — .249 loss in melting = 2.451 per cent. silicon in casting.

Suppose the composition of pig and scrap available are given and metal of a specified composition is required, say 2.451 per cent. silicon.

2.451 + .249 loss in melting = 2.7 per cent silicon to be in the calculated mixture. (1) To make up a charge of 10 cwts. of the two pig irons. "B" containing 2.25 silicon is the lowest. "A" containing 4.00 is 1.75 above it. The required content is 0.45 above "B."

Now weight of the 4 per cent silicon iron × 1.75 = 10 cwts. required iron × 0.45 or weight of 4 per cent. iron required = 4.5 ÷ 1.75 = 2.57 cwts.

Weight of iron containing 2.25 per cent. silicon = 10 — 2.57 =

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[1] Geo. Hailstone, in *Iron and Coal Trades Review*, Vol. 77, pp. 2,707.

7.43 cwts. This may be checked up by calculating the silicon content of the mixture as has been explained.

2. To make a similar charge containing, in addition to the pig, 30 per cent. scrap, which has a silicon content of 2 per cent. 10 cwts. charge at 2.7 per cent. = 27 cwts per cent. 3 cwts scrap at 2 per cent furnish 6 cwts per cent. 7 cwts. of two pigs must contain 27 — 6 = 21, or average of 3 per cent. Pig "B" has 2.25 per cent.

Pig "A" has 4 per cent, is 1.75 above "B" 3 per cent. desired is .75 per cent. above "B."

Hence cwts. "B" × 1.75 = 7 cwts × .75 = 5.25 5.25 ÷ 1.75 = 3 cwts. "B" required 7 — 3 = 4 cwts. "A" required. May be checked up as before.

Any number of similar examples could be given showing it a very simple matter to mix any number of varieties to get a desired content of any one element. It requires a more complicated calculation to obtain the desired quantities when all the ingredients are specified. However, it will be found that there may be a number of combinations that will give the proper content of any one element. These may be worked out for other elements and the best combination selected. If uniform melting conditions are maintained, it will be found easy to obtain a combination accurate to specification within 0.1 per cent in all elements.

Of the physical tests, those of cross breaking and tension are most important. One of the chief tests to a foundryman is that of shrinkage.

That of Keep consists of casting two one-half inch squares bars twelve inches long between the ends of a metal yoke.[1] The shrinkage is measured when the bars are cold by inserting a tapered scale between the yoke and the end of the bar. The yoke is made fairly heavy so that, by breaking the end of the bar the chilling action can easily be seen. The basis of this system is the influence of silicon on the carbon in iron causing the carbon to go from the combined to the graphitic state during cooling. Provided the iron contains sufficient carbon for the silicon to act upon, the quantity of silicon to be added can be varied to produce grades of iron in which any proportion of combined carbon and graphitic carbon can be obtained. It is asserted that if equal amounts of shrinkage exist in different specimens, the silicon and other elements are exerting similar influences upon the carbon, and that the specimens possess similar qualities as regards strength and hardness, also that the amount of shrinkage is a measure of the proportion of silicon present.

Keep's system gives the following results:—

Stove grate iron	.12
Medium sized ordinary work	.14
Maximum transverse test	.16
Maximum tensile test	.18
Grey mottled foundry iron	.20

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[1] See F. J. Cook, *Iron and Coal Trades Review*, Sept. 11, 1908, Vol. 77. also Joseph Horner, *Engineering*, Jan. 13, 1911, pp. 47.

The above tests are useful signs of the workability and to a certain extent the strength of iron in cases where the sulphur content of the coke and metal are fairly constant.

Testing machine is required only for tensile and cross-bending tests and may be quite simple. There is practically no extension in cast iron yet, much can be gained from the tensile test. The transverse test, the oldest one of all, however, is much more useful, as it includes the capacity for deflection before fracture, which is a property of much utility. The standard test bars are two inches by one inch, and twelve inches long. Results depend largely upon whether they are poured with the casting or separately, whether poured horizontally or vertically, how cooled, relation of thickness of test bar to thickness of casting, whether, if cast on edge, lower or upper edge is placed uppermost in the machine, and a great many other conditions that make the judgment of the operator the primary factor in the usefulness of the tests.

Hardness is usually tested in castings to be machined by recording the number of revolutions of a standard drill required to drill a hole of a given depth. The scleroscope is used most in scientific work and compares the hardness of the sample to that of hard steel, which is rated at 100. The capacity or tendency of the iron to develop shrink holes and spongy places is measured by casting samples shaped like the letter K, breaking them at the junction of the arms and comparing them with the set of graduated samples. If there is any such tendency in the iron it will be seen at the junction of the arms.

Working

The construction of the plant and machinery is hardly within this scope of the article. It may be said, however, that the main factors are convenience and progressiveness of operations. The cupola should be so constructed that the tuyeres flare out towards the inside so that as much air may be blown in at low pressure as possible so as to prevent oxidation and hardening effect and give high temperatures. A large receiving ladle should be provided in which the metal may stand before being poured to allow occluded and generated gases a chance to escape as well as to permit reactions between manganese and the sulphur, etc., and also permit the addition of deoxidating and other agents.

It is important to provide means of drying certain parts of moulds and thus induce more uniform cooling of castings.

Blast pressures are also very important factors, and, in order to govern quality of product, they should be kept constant.[1] Normal pressure is from .75 to 1 pound per square inch. This means from 21 to 28 inches of water. Gauges are fitted to most modern cupolas. Blast must supply about 650 cubic feet of air per minute per ton of iron. The term "melting ratio" is very indefinite. Depends on the character of the blast and fuel, the nature of the casting produced

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[1] Joseph Horner, *Engineering*, April 27th, 1910, pp. 539.

—light or heavy, proportion of wasters, duration of cast, etc. 10 or 8 to 1 represents good average practice.

Probably the most important mechanical agent affecting the condition of the carbon as far as the working is concerned is the rate of cooling. It has been shown that, if the rate of cooling be slow enough there will be a precipitation of graphitic carbon under almost any other conditions. The late Sir Lowthian Bell cast a 6-ton block of white iron to prove that, by slow cooling, there would be a precipitation of graphite at the center. On the other hand, by suitable chilling, iron of almost any silicon and carbon content may be made perfectly white. The effect of different thicknesses and consequent different rates of cooling was shown by Mr. W. H. Hatfield by casting a block 6 inches square on one end, about 2 feet long and tapering to a thin edge at the other end. All degrees of hardness were obtained in the one casting from coarse grey at the large end to hard white at the other end.[1]

The following experiment of Mr. W. J. Keep goes far to show the difference in physical properties of iron taken from different parts of the same casting which are primarily due to different rates of cooling.[2] A block of cast iron nine inches square and eighteen inches long was cut longitudinally in nine pieces and test bars 1.13 inches in diameter were turned from each piece. The average tensile strength of the bars was—

25,100 pounds	-	from the corners
19,913 pounds	-	from the sides
15,730 pounds	-	from the center

Very few realize that a variation in the size of a casting causes a greater variation in its strength than would a variation of the the chemical composition. The following tables may be taken as reliable results of tests in tension and compression to show the average properties of the irons named.

Next to rate of cooling in effect upon the condition of the carbon should be mentioned the temperature to which the iron has been raised in the furnace. Most agents that tend to produce combined carbon tend to lower the melting point. The higher the furnace temperature, the more refractory the product becomes and the larger the graphite flakes upon cooling.[3] Also the amount of carbon that can be absorbed by the metal is increased as this temperature is raised.

A fairly free use of fuel is desirable where quality of castings is a primary consideration. Along with a little limestone—50 to 60 pounds per ton—a much more fluid slag is produced, which tends to fall down through the fuel instead of clogging the cupola and by floating on top of the iron, protects it in a large degree from oxidation. The higher temperature also permits a freer evolution of gases. The manganese silitate and manganese sulphate can carry the oxides and sulphur to the slag much more easily than in a moderately cold iron. Besides, it is much easier and more beneficial to allow iron to cool if too hot than to increase its fluidity by adding phosphorus or other agents in the ladle.

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[1] *Engineering*, May 19th, 1911, pp. 670.
[2] Transactions A. S.M. E., Vol 25, pp. 914.
[3] E. Adamson, *Engineering*, Oct. 13th, 1911, pp. 507.

Coke

In furnaces where the fuel and metal are mixed, certain constituents of the former are transferred to the latter. For this reason as well as the effect upon slagging and heating qualities, all receipts of coke should be analyzed and unsatisfactory lots rejected. Accepted article should not contain more than 8 per cent. ash, not less than 88 per cent. fixed carbon, and on no account, more than 0.75 per cent sulphur, and if even 0.3 per cent. sulphur were specified, the advantages derived from itsuse would far outweigh its extra cost. Hard coke is likely to have more ash than soft, and it is usually the case that greater ash means greater sulphur content.[1]

TABLE X

No. of series	Crushing Tests	% CdC.	% Si	Comp at load of 14000	16000	22000	Max.
	Soft steel......	0	0	.00295	.00345	.00490	44200
17	0 White C. I. ..	2.85	0.81	.00400	.00465	.00645	123520
19	0 Car Wheel C.I.	0.99	0.72	.00570	.00650	.00955	61211
18	0 Heavy Mach.	0.52	2.09	.00330			
13	0 Stove Plate	0.10	3.22	.00730	.00855	.01325	48960

No. of Series	Tensile Tests	% Cd C	% Si	Extensions at load			Max.
	Soft steel			.00305	.00365	.00525	58320
17	0 White C.I.	2.89	.81	.00400	.00460	.00645	24000
19	0 Car Wheel	.99	.72	.00310			30000
18	0 Heavy Mach.	.52	2.09	.00500			24000
13	0 Stove Plate	.10	3.22	.01460	.01995		16850

Sulphur limit is generally placed at 0.5 per cent. Suppose one coke to have 0.5 per cent. more sulphur than another. If all the sulphur in the coke went into the iron and the melting ratio were ten to one, the increase, in the metal tapped out would be .05 per cent. in one case over that in the other, an amount equal to the original specified limit of the pig iron. Of course, not all the sulphur in the coke goes into the iron, but often the greater part of it does and is worthy of consideration.

In general, the requirements of a coke are:—[2]

(1) Should be strong and hard so as to resist disintegration in transit and crushing by weight of the charge. Many small pieces

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1. J. E. Johnson, *American Machinist*, Vol. 26, pp. 1451.
2. E. L. Rhead, *Engineering*, July 15th, 1910, pp. 107.

are likely to get mixed with the slag and cause "choking" of the furnace.

(2) Should be dense. This determines the ease with which coke ignites and the freedom with which it burns. The denser the carbon the higher the blast pressure that can be employed. Soft coke loses strength rapidly as it is heated and s more liable to crush and interfere with working of the furnace. Density of the mass also determines the concentration of heat possible. Thus, dense coke yields high local temperatures by using more of the air blown in in smaller compass. With lighter coke the heat is more diffused and the melting zone rises further above the tuyeres. For hard coke it would be better to have the air come in to the furnace tangentially so in order to retain it as long as possible in the melting zone.

(3) Should have a good cell structure.
(4) Should be as free as possible from ash.
(5) Should be uniform in texture.

Non uniform coke is as bad as soft coke. It is extremely hard to regulate the blast and the consumption is increased when it is used.

Ash makes the coke poor, necessitates more flux and often contains iron pyrites, which is very high in sulphur.

Coke giving a red ash is more likely to contain a larger percentage of sulphur. The red color is due to oxide of iron (ferric oxide) produced by burning off the sulphur from the sulphide of iron and converting the iron into oxide. If it gives a white ash it is likely to contain little sulphur although the element might be present as sulphide of lime. If iron, during melting, come in contact with iron sulphide, it will, in most cases, dissolve and take it up. Other sulphides may be decomposed and the sulphur taken up by the iron. These additions are very hard to prevent if the sulphur be in the coke. The production of an easily fused slag that will run freely greatly favors the passage of sulphur into the slag and sufficient lime should be used to effect this. The use of fluorspar assists in producing fluidity and presents the lime in a suitable form to attack the sulphide of iron. Viscous slags of a cindery nature favor the passage of sulphur into the metal. High melting temperatures produce greater fluidity and quicker separation of the metal and consequent less absorption of sulphur. This, of course, means that better coke, even though as much sulphur may be present as in inferior kinds, will do less harm to the metal. Thus, increased temperature favors the exclusion of sulphur and phosphoric pig of lower melting point and greater fluidity are less affected than refractory irons that melt sluggishly. Similarly slow-working and hanging of the furnace will tend to more sulphur.

Sulphur is present as sulphide of iron, calcium sulphate and possibly other forms. Its presence is easily detected by the odor of rotten eggs (H_2S) produced when burning coke is quenched. Sulphur dioxide is also given off in burning but is less easily distinguished. Thus, it is seen that other qualities than low sulphur in the coke contribute to low sulphur in the iron.

Iron for Particular Uses

There is no doubt that iron can be made much more satisfactory if its use and condition of employment be known, both by special treatment and suitable chemical composition. Tests have shown that the harder metals are stronger in compression than the softer ones. The latter, however, give greater deflections, are tougher and are more suitable for parts subject to shocks. For very close grained gas engine work the grain should be as fine as possible without making the castings too hard. This means low melting temperatures and often the composition known as "semi-steel" is used for this purpose. Some purposes require certain combinations. For instance, the best mixture for making enameled ware is given as carbon 3.5 per cent, silicon, 2 per cent., phosphorus, 1.5 per cent., and manganese 0.6 per cent. by the best German authorities. For chemical plants, Professor Daniell showed by many experiments, that grey iron is attacked three times as rapidly as white.[1] Thus, in cases where tanks to contain H.C1 are required, it is best to cast them around collapsible chills, thus obtaining a backing for the white iron to give the necessary strength.

Summary

There are a few simple rules that should be remembered as the basis of working knowledge. The different agencies that affect the quality and properties of the product overlap in their effects, sometimes neutralizing and sometimes accentuating one another. Hence, in order to control the output, most of these influences should be kept constant. The introduction of chemical analysis has made possible the elimination of one, for a long time very troublesome variable.

It is well to bear in mind that, for a given composition, the smaller the particles of graphite the stronger the iron. A cast iron of maximum strength should have a metallic matrix of maximum strength, which means that the matrix should consist of pearlite or with but a slight excess of cementite which, in turn, means that the combined carbon should be somewhere between 0.7 and 1.0 per cent.[2] These, and many similar conclusions may be deduced from the foregoing article.

The steadily advancing cost of labor as well as sharpening competition is greatly increasing the necessity of reliability in the production of castings. The percentage of "westers" allowable is becoming less each year, and, in fact, is required by most firms to be reduced to a minimum. For these and other reasons, the chemist and the testing plant are as necessary to the foundry as is the raw material. Nevertheless the long experience and practiced eye are even more essential to the man in charge than ever before, for, as has been shown, the results of tests and analysis are always qualified by a host of conditions all of which must be taken into account. The effect of research has been to deduce a cause for each property, queer or otherwise, belonging to the iron. So that, while machinery and appliances have greatly simplified actual operations; to say nothing of the quickness of decision and promptness of action necessitated by the nature of the operations involved, keenness of perception and soundness of judgment must always be the primary requisite qualities of the "man behind the gun."

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[1] F. J. R. Carulla, in *Iron and Coal Trades Review*, Vol. 76, pp. 1951.

[2] W. J. Keep, Transactions American Society of Mechanical Engineers, Vol. 26, pp. 483.

AT THE CLOSE OF THE COLLEGE COURSE.

By J. Lanning, '11

Free, free, free—the one word in the whole realm of thought which can give expression to the idea uppermost in the student mind of the Fourth Year Class, as the echoes of "farewell" cheers grow fainter and fainter, and finally die away along the corridors of the various examination halls, when the last paper for the degree of B.A.Sc. has been handed in to the presiding examiner.

Free from the irresponsible entanglements of college life; free from the immediate spirit of college sports and class associations; free from the insipid monotony of lecture halls and the strain of examinations; free from much that is weary, from a little that is hopeful and from all that theoretically ideal. Free!

Four years of college life at an end. It is indeed a moment which demands serious thought and consideration, one of the most important, perhaps, in the whole tide of the student's worldly interests.

It is the point of turning, the hour of change from indifferent and irresponsible academic conditions to responsible and productive professional life. Few of us, possibly, there are who fully appreciate the solemnity of such an occasion, our interests are so wide, varied and divided. Excitement attendant upon the packing of trunks, the hustling together of old notes, books, laboratory reports, perhaps never to be reviewed again, the buying of the railway ticket to the home-town, has necessarily obscured the issue of this important hour to many members of the class.

Others, farther removed from the influences of home and its many blessings, gravely pay our last week's room rent, count the available change and seriously consider hitting the trail to the backwoods in quest of a job. Some are happy, optimistic, others indifferent, giddy as in balmy freshmen days when we were "everything by starts and nothing long," others still are grave, pessimistic, and all so different one from another.

A few even are ambitious, while others don't care a hang.

Just as in the crowds which throng life's busy thoroughfares are all sorts and conditions of men with varied outlooks upon the future, wherein keen intellects, careless ease and smug satisfaction jostle one another and pass on, so in college halls, indifference, ambition and thirsting intellects meet together, for a season, partake in common, and then are gone to meet together no more.

The history of our class on the journey through the Science course does not differ materially from that of other classes who have gone before. Many who began well in freshman days with enthusiastic desire to follow to the end, have fallen by the wayside.

The examiner's sword has been active through all the years, and the consequences have been most sorely felt. The choice at times might have been open to question, and the really deserving of every consideration sidetracked by the irregular falling of the sword, yet the issue remains, and from the original class of 325 who signed the roll in the autumn of 1908 only 187 have come through the fires of examination, inconsistency and providential interference.

Though we have been permitted to come thus far along the route, we realize that the most severe pruning has yet to be undergone—the pruning which invariably follows when theory and practice meet and compromise.

From every class that has gone before there are records of successful men. Failures there are also. Our class may prove no exception. It is but to be presumed that from every group of 187 men, some, when weighed in the balance by the demands of industry and enterprise, will be found wanting.

Men who fail, however, are not necessarily failures, and the divine charity which has a place in every student's soul forbids any syndicate to be formed of those who lack in the struggle for place in professional life.

The field of endeavor which lies outstretched along our horizon on this occasion is that of the whole round world. There is no region yet known to man where the School of Science graduate finds no scope for his best efforts.

Through all the vast prairie country of the West he may be found engaged enthusiastically in the great work of development and economic utilization of Canada's abundant natural resources.

Through the wilds of the northlands he wanders and demonstrates his engineering skill, wherever the spirit of colonization has taken root.

Nor does he confine his efforts to Canada and Canada alone. He has established himself in every continent and island, whereever industry and enterprise need development for the benefit of civilized man.

Australia has her mining and civil engineers whose names are enrolled on the School of Science calendars. South Africa, Europe, South America, even rebellious Mexico, are fields wherein old graduates of Toronto University are privileged to tarry.

This is the wide range which opens out, to Science students particularly, as they stand in silent contemplation for a short while on a bridge of their own construction between the academic and professional life. It is but natural to expect that in such a large field we shall drift far apart from one another as we plod along in the struggle for place.

The electrician will have little in common with the mining engineer.

The former enters the open doors of manufacturing houses, electric laboratories, and extensive power plants in great industrial centres, the latter travels off to the lonely wilds of the northland where the coyote howls by night, and where vast treasures lie undeveloped and unknown. The civil engineer will seek the rapidly growing towns and villages of the Western Provinces and become involved with the intricate problems of municipal life.

Others will follow the iron road to the end of the line and aid in opening up to transportation and civilization unexplored and undeveloped lands. Each and all will play some part in the great struggle of nation building, of colonization and of ideal citizenship.

Others are closely following on our heels along the trail we have come. Every year is a fourth year to some class, but to the individual it comes once only, and then the choice is made, on which depends largely success or failure in after life. Four years of college work and associations create great changes in the student and his ideas. We entered as boys, care-free, from town and country, from farm and hill, from the provinces of the West and from the islands over the sea; we pass out as men, in discretion, may we hope, as well as in years. Plans also have changed. We came teeming with all that we hoped to do; we leave, realizing how little we have done, how unprepared we are to face the great problems of industrial life, sadder but wiser men. We came with ideals, believing steadfastly in the completeness and perfection of a college course; we leave with ideals shattered by its very incompleteness and imperfection, realizing that our life's real study has only begun. It is this very shattering of ideals, consequent upon the incompleteness of four years of study, that establishes the cord of loyalty between the student and his *Alma Mater*, and most loyal is he who has the fullest realization of the price he has paid.

That each and all the members of our class of 1912 will choose wisely and do well to the honor and glory of the Empire, their country, and their *Alma Mater* is the sincere and fond wish of one who has interests in common, and a human love for all mankind.

ADVANCE IN MOTOR CAR DESIGN

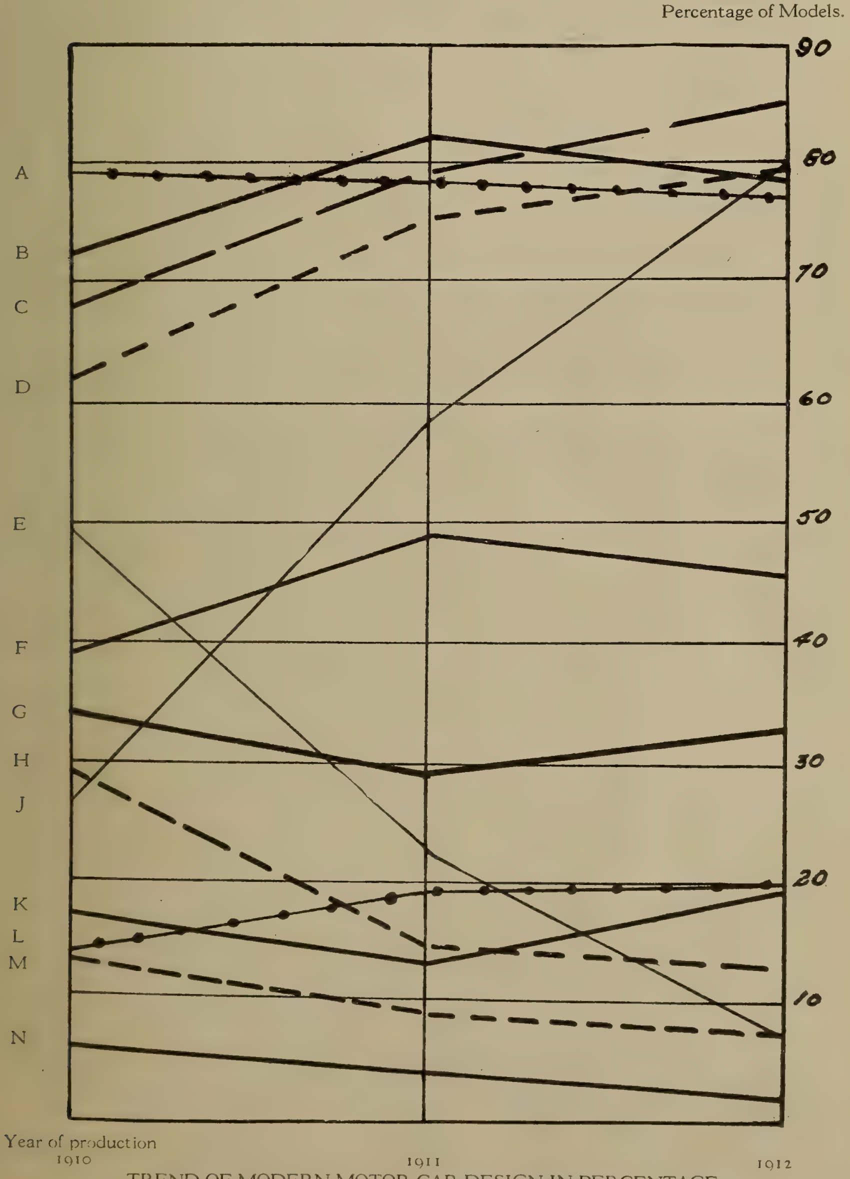
G. C. PARKER, '10, in the "The Motor Magazine."

Considering one of the primary factors governing the manufacture of motor cars, viz., price, there is by far the greatest demand for cars of low price, that is, cars which sell for prices ranging from $1,000 to $2,000. The demand for cars of this class is not as great this year as heretofore, while that for higher priced cars is somewhat greater. The number of cars selling below $1,000 is about the same. The increase in number of high-priced cars on the market indicates confidence on the part of the motoring public that the motor car is here to stay, and will be of ever increasing benefit. In 1911 the low-priced car was the favorite, but this year the increase is in favor of the car selling from $4,000 to $5,000.

In the design of the car one of the first things to consider is the size, or wheel base. There has been, and no doubt will be, no end of discussion as to the best wheel base for general uses. There is no doubt in the minds of designers and buyers that for touring and country road work the long wheel base is in every way desirable. The riding qualities resulting from the use of a large wheel base are well known. For town work the short wheel base is desirable on account of the ease of turning and driving in congested traffic. Taken in a general way, it is found that there is a tendency to increase the wheel base, and that the most popular appears to be in the neighborhood of 120 inches. There has been a marked increase in the number of manufacturers making cars of this size, and a still greater increase in the cars having a greater base than 127 inches. On the other hand, there has been a decided falling off in the number of cars under the 110-inch mark. From the above, it is seen that for the time being at least, the designers have decided that a wheel base of 120 inches and greater is the best.

The question of the number of cylinders is one governed chiefly by price. The four-cylinder engine is suitable for all classes of cars, and is to be found in both the high and low priced cars. There is, however, a decided tendency on the part of manufacturers to invade the realm of the medium priced four-cylinder cars with the six cylinder. This is a case of history repeating itself. A few years ago it will be remembered that the medium, and especially the lower priced cars were almost universally fitted with two cylinder engines, and, in many cases, single cylinder engines. For a time the dividing line between the high and low priced cars was also the dividing line between the four and two cylinder engine. The manufacturers, however, soon found it possible, and perhaps necessary, on account of keen competition, to build a four-cylinder engine to replace the two cylinder model, and to sell it for a comparatively low price. In the same manner it has come to pass that a number of cars equipped with six cylinder engines are being sold for the same price as the four cylinder cars. As will be seen from the chart, the four cylinder engine is used on 78 per cent. of the cars manufactured for the present season. There has been a decrease in the number of cars equipped with two cylinders, and a greater increase in the number of six cylinder cars.

Owing to improvements in motor design the ratio between weight and power has been increased. In other words, the pounds per horsepower has been lessened. This has been made possible



TREND OF MODERN MOTOR CAR DESIGN IN PERCENTAGE OF MODELS MANUFACTURED

A—Water Pump. B—Four cylinders. C—Dual ignition. D—Bore less than Stroke. E—Mech. oiler. F—Valves on same side. G—Valves on opposite sides. H—Bore = Stroke. J—Circular oilers. K—Six cylinders. L—Thermo syphon. M—Bore greater than Stroke. N—Two cylinders.

by the use of materials of greater strength and lesser weight, and also by the increase in piston speed, allowing smaller moving parts, and hence giving a reduction in material. This has led to the use of engines of greater power, and, while there has been an increase in the use of engines of from 35 to 45 horse-power, the tendency is for higher powers. The day of the low powered car appears to be over, and the horse-power is steadily increasing.

A subject connected with the power of the motor is that of stroke. During the last year or so, this has been uppermost in the minds of designers, both in this country and abroad. In fact, there has been almost a complete reversal of opinion in Europe on this matter. It is not many years since the short stroke motor was in general favor. By the short stroke motor is meant the motor in which the stroke is equal to or less than the bore. European engineers were loud in the praises of the short stroke, and the design was generally adopted. In America this was not so noticeable. There were a number of manufacturers who advocated the short stroke, but, on the other hand, there were many who felt that there was not sufficient justification for this.

The last year has seen a tremendous increase in the number of makers using the long stroke motor. Those who favored the "bore equal stroke" design, have increased the stroke, while those who used the longer stroke have increased it to a greater extent in their new models.

The function of the clutch is to provide a flexible method of connecting the engine to the driving shaft. On account of the inherent property of the gasoline engine, which necessitates its running at high speed before it is capable of carrying its load, some means must be provided for applying the load gradually. Obviously the most satisfactory method of doing this would be by a device that had the property of slipping. This is the principle of the clutch, and the amount of slipping depends on the nature of the surfaces in contact. In the cone clutch the slipping, and consequently the wear, takes place between two surfaces only. In practice one of these surfaces is of a soft material, confining the wear to one surface only. In the multiple disc clutch, the discs are of metal, and the wear is distributed. The number of discs may vary from four or five to forty or fifty, depending on the design. The fewer the discs the greater must be the area of the surfaces, and this will result in a greater diameter for the same power. The chief objection to this is added weight in the clutch, with added diameter, which will result in greater inertia. This causes the clutch to rotate for a considerable time after release.

The band clutch, in principle, is the same as the band brake. It consists of a flexible band or two rigid sections which expand in a cylinder. The band is attached to the clutch shaft and the cylinder to the engine shaft. The method of applying is similar to that of the other types.

When changing from one speed ratio to another, especially from a lower to a higher, it is necessary for the clutch shaft to decrease in speed in order that the gears may mesh without "grinding." If left free when released, the inertia of the clutch will cause it to revolve at a high rate of speed for some time after the release. In order to reduce the speed it has become customary to equip the car with a clutch brake. This consists of a small disc or shoe attached to the frame of the car, and normally disengaged from the clutch. As soon, however, as the clutch is released, some part of the revolving section comes in contact with the brake, and the rate of rotation is lowered, thus allowing the gears to be engaged.

The tendency in the design of the transmission gears is toward the introduction of another speed. The number of models with the two speed gear has practically ceased to exist, and while the three-speed gear has shown a slight falling off, the greatest increase is in the models employing a gear set with four upward speeds. This gives two choices of speed between the low and the high, which in heavy cars is of great advantage. When used intelligently the use of the four-speed gear on the heavy car relieves the engine, especially when the car is negotiating a heavy grade or rough roads.

By far the most universal addition to the 1912 models is the self starter. These operate on four different principles, viz., mechanical, electrical, compressed air, and the explosion of gas in the cylinder. Of these the latter is the most popular, and adds but little weight to the car. Gas from the lighting tank is admitted to the cylinders through a reducing and distributing valve. The spark is then placed and the gas in one of the other cylinders will explode, turning the engine over. The compressed air system consists of a small pump connected to the engine, this charges a reservoir under pressure. To start the engine the air is admitted to the cylinders, and the engine is started as an ordinary air engine. The chief advantage of this method lies in the fact that the engine is started from rest gradually, thus imposing no undue strain on any of the parts. For the use of the electrical system there is a small electrical generator driven by the engine. This charges a storage battery, which, in turn, drives the generator as a motor when it is desired to start the engine. The generator can also be used for ignition and lighting, in connection with the storage battery. The mechanical arrangement for starting consists usually of a rachet wheel which engages the crankshaft and is operated by a foot or hand lever. It is simply a refinement, bringing the crank to the driver's seat. Without doubt the adoption of the self starter has done more to popularize the car than any accessory that has been introduced for some time. It makes the gasolene car capable of being driven by the fair sex without placing them under the necessity of asking some passer-by to turn the engine over for them.

Taken all in all, the tendency in the design of cars for the present season has been more in the direction of general refinement and higher quality than in lower price. The manufacturers evidently believe in bringing the manufacture up to a high standard rather than down to a price. Every development tends to make the car easier to handle, more reliable and more comfortable for the occupants as well as to decrease the cost of maintenance and running repairs. There is, no doubt, still vast room for improvement. Take, for example, the case of oiling and cleaning. There is little doubt that in the cars manufactured a few years hence it will be much easier to clean the cylinders and transmission case than in the present models. During the days of the early type of car with the engine under the seat, the owner did not examine his engine any more than was absolutely necessary, on account of the necessary trouble and labor entailed by a complete examination. In the models in which the engine is under the hood, the disagreeable part of this has been done away with, and the opinion is that in future this idea will be carried out to a greater extent. No car is built to run continually without occasionally tightening up and examination, and the easier this is to accomplish, the oftener it will be done, and this will without doubt improve the running qualities as well as lengthen the useful life of the car.

BIOGRAPHY

The eminent engineer who holds the renowned position of being foremost in the faculty calendar is Mr. J. L. Morris, 1881. He was born in Greenlaw, McNab, County of Renfrew, in 1862, was educated at the Pembroke public and high schoools, and entered the School of Practical Science as a matriculant of the University of Toronto in September, 1878, from which he graduated in April, 1881. Mr. Morris spent the first summer after graduation on a Dominion Government survey in the North West Territories, in the vicinity of Fort Calgary. The following three and one-half years were spent as assistant to the engineer in charge of construction of the Eastern Division of the Canadian Pacific Railway between Mattawa and Missinabie. From June, 1885, until the close of 1886, he was on maintenance of way for the Canadian Pacific Railway between Montreal and Port Arthur. From that time up to the present, Mr. Morris has been in private practice in Pembroke, Ontario, as civil engineeer, architect, and land surveyor. The firm has been known as Morris & Moore since January of 1909.

Mr. J. L. Morris, 1881

In June, 1885, Mr. Morris prepared a thesis with accompanying plans on "Masonry and Temporary Works" for the degree of C.E. Toronto University. He was granted the land surveyor's certificate for the province of Ontario in September of that year. He became an associate member of the Canadian Society of Civil Engineers in February, 1887, and a member in January, 1904. He is also a member of the Ontario Association of Architects since 1901.

Among the many engineering enterprises upon which he has been engaged and pertaining particularly to the design and construction of permanent bridges, since his taking up private practice in Pembroke, may be cited the following: a stone arch bridge in Pembroke costing $20,000., and another over the Bonnechere River at Eganville costing $16,000.; a steel highway bridge of five spans over the Madawaska River at Claybank casting $30,000; a single steel highway bridge over the Bonnechere River at Horton costing $9,000.; another steel highway bridge, a single span over the Indian river, Pembroke, costing $7,500., and a three-span steel highway bridge over the Bonnechere River at Renfrew costing $8,000.

Mr. Morris was manager of the W. J. Poupore Co., of Montreal, on the construction of the Chateauguay and Northern Railway from Montreal to Joliette, and the sub-structure of the Bout de L'ile bridge over the Ottawa River in 1905, the cost of the sub-structure being $150,000.

He designed and superintended the construction of a sewer system for the town of Pembroke in 1899. This included an outlet 2,400 feet in length under the bed of the Ottawa River to deep water. He likewise designed for the town of Prescott a sewer system, septic tank and outlet, in the year 1910. He designed and superintended the construction also of a power plant and transmission line from Black River to Pembroke, a distance of fourteen miles, 1908, the cost amounting to $150,000.

Mr. Morris has been senior partner in the firm of Morris, Mackie & Co., on the construction of a section of the Transcontinental railway including the Armstrong yard and round house, since 1910.

Among engineers who find themselves so completely engaged in their profession, it is but seldom that a sacrifice of time is made for preparing for the technical press, articles based upon the work on which they are engaged. We find, however, that Mr. Morris has not ignored this important feature of every engineering experience. In 1888 he compiled a paper entitled "Masonry Foundations" for the Land Surveyors' Association, to be followed in 1890 by anoother entitled "Compass Lines" for the same Society. In 1906 he presented a paper to the Canadian Society of Civil Engineers upon the Bout de L'ile bridge.

During the thirty-one years that have elapsed since Mr. Morris graduated from the School of Practical Science he has engaged in various branches of engineering, and with like success in all. Apart from the credit due to him for his ability as an engineer, this success shows that even in the early days of this institution the value of broad general training was recognized and well taken care of by our worthy Dean.

BRANCHES OF THE ENGINEERING ALUMNI

The various branches of the University of Toronto Engineering Alumni Association, with their presidents and secretary-treasurers, are as follows:—

Montreal Branch—President, G. H. Duggan, '83; secretary-treasurer, H. W. Fairlie, '10, 657 Dorchester St. West, Montreal, P.Q.

Pacific Coast Branch—President, E. B. Hermon, '86; secretary-treasurer, N. R. Robertson, '06, 202 Winch Bldg., Vancouver, B.C.

Pitts burg Branch—President, Gardiner Alison, '03; secretary-treasurer, M. L. Miller, '03, 206 Suburban Ave., Pittsburg, Pa.

Toronto Branch—President, J. C. Armer, '06; secretary-treasurer, H. Irwin, '09, Engineering Building, University of Toronto, Toronto, Ont.

Temiskaming Branch—President, E. V. Neelands, '00; secretary-treasurer, H. W. Sutcliffe, '07, New Liskeard, Ont.

The interests of School men residing in New York City are ably looked after by the University of Toronto Club of New York, of which Dr. Charles Graef is president, and T. Kennard Thomson, '86, 30 Church St., New York, is secretary-treasurer.

There is urgent need of branches being formed immediately in Ottawa, Winnipeg, Regina, Calgary and Edmonton. In each of these centres between 25 and 50 graduates are located, while the men in the immediate vicinity would slightly increase these numbers, forming in each instance an ideal working body in which matters pertaining to the Faculty of Applied Science and its graduates could be ably discussed. We hope to hear of these branches being formed.

OBITUARY

A shade of gloom was cast over the University upon the arrival of the news of the death of Mrs. Dushman, wife of S. Dushman, Ph.D., of the Department of Electrochemistry. Mr. Dusham had but recently taken up his location at Schenectady, N.Y., where he was to have engaged in original research during the summer. In less than two weeks after their departure from this city, however, Mrs. Dushman was seized with appendicitis and lived only a few days. The remains were brought back to Toronto for burial. Dr. Dushman has the sincerest sympathy of his many friends and acquaintances in the Faculty of Applied Science and throughout the University.

Equally sad is the misfortune which befell Mr. O. B. McCuaig, a graduate of '07. Mr. McCuaig was engaged as general superintendent of the Winatchee Light & Power Co., of Winatchee, Washington, since resigning his position as chief engineer on telephone construction on the T. & N. O. Railway. Mr. McCuaig had the misfortune to lose his bride of a year who died suddenly in Washington a few weeks ago. To him also we extend heartfelt sympathy.

APPLIED SCIENCE

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DEVOTED TO THE INTERESTS OF ENGINEERING, ARCHITECTURE
AND APPLIED CHEMISTRY AT THE UNIVERSITY OF TORONTO.

Published every month in the year by the University of Toronto Engineering Society

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EDITORIAL

BIOGRAPHIES OF GRADUATES

We strive to interest our graduate, and find that in the rush of summer business, while he keeps the venturous public constantly picking steps over freshly laid side walks, gaping trenches, and road beds in the making, his desire for reading does not denote the task to be easy. His time for reading confines itself to narrow scope, and it must be of real interest to command attention. In a new department entitled "School Men," beginniing with this issue and to appear continuously, we hope to supply something of interest to every one who receives the Journal. Its information, furthermore, will be thoroughly reliable. Its pages will be perused by students to whom they will monthly disclose the vast breadth of engineering fields and the adaptability of graduates of this institution to them. Class mates need not be prompted to read the biographies of their one-time fellow students and constant associates in the profession. In short, every one will, it is expected, take kindly to the biographies of "School" men; and to render the department useful by its completeness APPLIED SCIENCE solicits a biography similar to the one published in this issue, from all graduates. As many will be published as space given to the department will permit.

This is not merely an incentive to collect material for publication. We want all the information that can be had regarding the professional standing of graduates of this Faculty. The material with which the graduate supplies us is being put to another use, that of establishing for the engineering alumni a record of all its members. More is said of this in another column.

TO GRADUATES

The circular letter which every graduate received a few days ago will be given his immediate consideration, it is to be expected. There is very incomplete information at hand about the professional work our men have been doing since graduation. The University of Toronto Engineering Alumni Association should have in some convenient form complete statistics regarding the lines of work the Alumni follow. The criterion of the value of the training given in any University must be sought for, and will be found, in its graduates. The Faculty of Applied Science has been most instrumental in furnishing the engineers who have built up the profession in Canada and elsewhere. Building up a profession in any country signifies building up the country.

We sometimes hear it said that the Faculty of Applied Science does not receive its due at the hands of the Board of Governors at the University. Whether this is or is not the case is a subject of grave importance to every graduate. We are all indebted to the School for advantages and favors and for the devotion of the men within its walls to the advancement of its good work, though the recompense does not compare with that of positions of similar responsibility and importance in other walks of life. There is this and other questions of equal importance to be answered by the graduates of the School. The significance of their answer is indefinable until the knowledge of the strength of School men in the profession of engineering is broadcast in general and brought home in particular to University authorities.

The graduate form which is enclosed in the circular letter will do a great deal towards assisting in compiling useful data concerning the output of the School and its place among other faculties of the University of Toronto. Indeed, a fairly complete return of these circulars is absolutely necessary. Again, the various branches of the engineering alumni—namely, those in Montreal, Vancouver, Temiskaming, New York and Pittsburg, are most interested in the progress of the School. Those who are so situated that they can affiliate themselves with any of these branches should do so as early as possible as important questions will undoubtedly be dealt with. Where a number of School men reside in other towns, similar branches should be organized and maintained. It is in this way that we can best unite our efforts in the furtherance of School affairs.

SCHOLARSHIPS

The circular letter mentioned in another paragraph contains information concerning what has been done by the Toronto Branch of the Engineering Alumni Association in the establishment of research scholarships in the Faculty of Applied Science. A number of applications have been received and many of them considered. Before awards are made in July, however, an opportunity is given to every graduate of the institution to apply, if he so desires, for one of these scholarships, and to this end an application blank was enclosed with the letter.

As stated, upwards of $1,000. has already been subscribed for this movement. This amount is the result of a number of requests for support that were made promiscuously by members of the executive. Other subscriptions which came unsolicited, and numerous enquiries regarding the enterprise have led to this call for the co-operation of all School men. The subscription form which was mailed in conjunction with the circular letter may be filled out and returned in the accompanying envelope, or at any other time. The application for scholarship, on the other hand, should be mailed before July. The graduate form, however, should receive earliest attention, be filled out as completely as possible, and returned in the enclosed envelope. We trust that this request, which is in the interests of all our readers, has received, or will receive, early attention.

MONTREAL GRADUATES' DINNER

The second dinner for the season of the Montreal branch of the Engineering Alumni was held on May 12th, the president, Mr. G. H. Duggan, being master of ceremonies. Unfortunately, many of the senior graduates were unable to be present, being absent from the city, and only about thirty men were in attendance. Owing to the busy season this was almost to be expected, but the enthusiasm which presided over the meeting is assuring that the Montreal dinner is a well established function, and that next year's attendance will be greatly increased. Two features of the evening that were most encouraging were: the presence of a number of "School" men who had not previously associated with the branch, many of them being unknown to quite a number of the younger graduates. The other feature was the manner in which the graduates who were visiting in the city accepted and enjoyed the hospitality of the meeting. The desire of the Montreal Club is to make these meetings the stamping ground of graduates in the city, and the officers of the association are doing a great deal to round up all "School" men within reach.

The "social and musical" evening that had been promised by invitation was not finally achieved until after some argument with "mine host," but the calisthenics of E. A. Thompson, '09, to the music of Madden were well worth the effort. "Babe" Reynolds, although compelled to leave early, entirely without incrimination, was much appreciated in a couple of his songs. His ability will be remembered at similar functions in future, at which no excuse of previous engagements will be tolerated.

Space does not permit a detailed account of all the evening's good entertainment. It only remains to be stated that there is a standing invitation for every "School" man in Montreal or vicinity to come and enjoy for himself the meetings of the graduates.

THE ALUMNI IN NORTHERN ONTARIO

The annual meeting of the Temiskaming branch of the Engineering Alumni Association was held in the Board Room of the Mine Managers' Association at Cobalt on April 30th. Major R. W. Leonard of the Board of Governors of the University of Toronto, was elected honorary president, while Mr. E. V. Neelands, B.A.Sc., '00, manager Hargraves Mine, Cobalt, is president for the coming year. The secretary-treasurer is Mr. H. W. Sutcliffe, O.L.S., '07, New Liskeard, Ont.

Representing Cobalt, Messrs. C. G. Williams, B.A.Sc., '03, manager of the Nova Scotia mines; B. Neilly, B.A.Sc., '07, manager of the John Black mines, and A. D. Campbell, B.A.Sc., '10, of the O'Brien mine, were elected to the Council. Representing Porcupine, Messrs. S. Thorne, B.A.Sc., '00, manager the Preston East Dome Mines, and F. J. Bedford, '08, are councillors. Haileybury and Liskeard are represented by G. T. Somers, B.A.Sc., '07; the T. & N. O. Engineers by R. Keys, '08, North Bay; Elk Lake and Gowganda by George Johnston, '00, and the Transcontinental Railway by Ross Harstone, '09, of Cochrane.

The roll of the Temiskaming branch includes the names of over 50 graduate members together with a number of undergraduates. Arrangements are already under way for the annual dinner next fall. It will undoubtedly be the largest reunion ever held by the Association.

EXPLORATION PARTY FOR THE NORTH

Mr. J. B. Tyrell, M.E., in charge of a party of engineers on exploration work for the Provincial Government, will leave in a few days for Winnipeg. From that city they will proceed north to Fort Nelson. Professor L. B. Stewart, O.L.S., D.T.S., professor of surveying and geodesy; W. B. McPherson, B.A.Sc., and R. B. Stewart, M.A., B.A.Sc., will accompany him. The party will be away until October or November and will be engaged on the survey of the mouth of the Hayes River and of Ontario's newly acquired territory on Hudson's Bay.

REGINA ENGINEERING SOCIETY

The Engineering Society of Regina, with members and guests numbering 65, held a very successful dinner on the 2nd instant. The president, A. J. McPherson, 93, acted as toastmaster. The dinner was largely attended by School men in the city. Mr. McPherson gave an exceptionally interesting address entitled "The Future of the Engineering Profession in the West," He emphasized the growing importance of engineering skill and various adaptations to the industries. In this regard he mentioned the wide field the engineering profession has in the development of Canada's coal, forest and water power resources, apart from the solving of the many engineering problems pertaining to this development. Mr. R. E. W. Hagarty, '07, replied to the toast "Canadian Industries" in a most able manner, pointing out Saskatchewan's peculiarly advantageous possibilities for industrial development. Mr. Thornton, in proposing the toast, observed how dependently Canada's world-wide industrial reputation rests upon the engineering profession. Mr. Martin, who proposed the toast "Our Railway Systems," spoke of the status of the engineer in the forefront of every problem of transportation, of water power, of water supply, etc. The alluring opportunities for engineers in Saskatchewan were among the foremost in the Dominion because of the great and as yet barely developed resources, and the engineering problems they have presented.

In proposing the toast to the "Engineering Profession," Mr. O.W. Smith spoke of the work of the engineer as being a service to humanity in the broadest sense of the term. The engineer is one of the important pioneers in all countries and the hardships and toil which he is so often compelled to face call for peculiarly strong qualities of character.

The reply was given by J. Darlington Whitmore, who spoke of the engineer as the painstaking servant of the community. The engineer serves the community by attending to the smallest details of household convenience and to the greatest works of transportation, not stopping short of laying his wires across the ocean bed.

At a meeting of the Albany Society of Civil Engineers, of which Russell S. Greenman is president, Mr. T. Kennard Thomson, '86, delivered an illustrated address on "Caisson Foundations." The meeting was held on April 22nd.

EXAMINATION RESULTS

NEW B.A.SC. MEN

Following is a list in alphabetical order of the successful men in the examination for the degree of Bachelor of Applied Science, University of Toronto.

Honors

J. Aitken, L. A. Badgley. T. W. Brackinreid, W. H. D. Brouse, W. C. Cale, W. W. Chadwick, R. B. Chandler, D. B. Cole, J. H. Craig, C. H. Cunningham, J. M. Duncan, J. A. Elliott, R. J. Fuller, F. G. Hickling, H. Hyatt, J. T. King, M. Kirkwood, J. Lanning, T. A. McElhanney, W. G. McIntosh, R. A. McLellan, R. V. Macaulay R. E. MacBeth, A. D. MacDonald, A. E. MacGregor, E. G. MacKay, H. H. Madill, J. E. Malone, J. H. Parkin, F. M. Pratt, J. E. Ratz, L. J. Rogers, F. V. Seibert, C. P. Sills, M. L. Smith, W. C. Smith, A. E. Stewart, R. A. Story, P. G. Welford, E. R. Williams, W. H. Wilson, W. J. T. Wright, A. Young.

Pass

L. B. Allan, E. G. Archer, W. J. Baird, T. H. Bartley, J. H. Billings, J. R. Bissett, W. J. Boulton, H. O. Brown, G. H. Burnham, P. G. Cherry, E. F. Chesnut, H. J. Clark, A. S. Cook, W. M. Crothers, F. K. D'Alton, W. B. Davis, F. C. DeGuerre, W. B. Dunbar, C. H. Eckert, C. F. Elliott, G. R. Elliott, W. J. Evans, K. A. Farrell, S. E. Flook, E. L. Frankel, E. E. Freeland, J. R. Freeman, J. M. Gibson, J. L. Gooderham, H. Goodridge, E. B. Graham, E. A. Greene, G. M. Hamilton, M. B. Heebner, H. R. Hill, O. H. Hoover, A. J. Huff, R. H. Jarvis, P. T. Kirwan, M. Lieberman, A. L. Long, A. W. P. Lowrie, J. B. McAndrew, H. J. McEwen, W. G. McGhie, D. A. McKenzie, A. J. McLaren, W. B. McPherson, A. A. McQueen, W. M. McAndrew, F. M. Macdonald, J. G. MacLaurin, G. G. MacLennan, A. W. R. Maisonville, N. Marr, J. C. Martin, C. H. Meader, L. G. Mills, J. A. Murphy, J. C. Nash, E. H. Niebel, C. K. Nixon, E. S. Noble, R. K. Northy, W. A. O'Flynn, J. A. Orr, J. S. Parker, J. McD. Patton, W. J. Perrin, B. W. Pick, L. J. Quinlan, F. N. Read, W. A. Richardson, W. E. Robinson, D. Ross, O. W. Ross, F. G. Rutley, F. R. Scandrett, Miss H. E. Scott, J. W. Scott, N. D. Seaton, M. R. Shaw, W. C. Shaw, R. G. Sneath, R. J. Spry, G. E. Squire, W. S. Steele, R. Stewart, R. Taylor, J. B. Temple, E. A. Ternan, R. D. Torrance, W. G. Tough, J. H. C. Waite, W. D. Walcott, R. M. Walker, G. L. Wallace, A. Wardell, F. E. Watson, B. W. Waugh, A. G. Wheeler, J. L. Whiteside, G. H. Wilkes, W. G. Worden, W. H. Wylie, S. Young.

Supplementals

The following men must take supplemental examinations in subjects indicated before they are eligible for the degree:—W. O. Boswell (electricity), E. O. Ewing (str. of materials), R. E. Green (electricity) A. J. McFadyen (3rd year astronomy and geodosy), F. H. McKenzie (str. of materials), M. H. Murphy (hydraulics), V. J. O'Donnell (electricity), H. Pullan (thesis), E. V. Reid (thesis), P. Sheard (thesis), F. H. Wrong (hydraulics).

The results for other years are given alphabetically below. A subject in parenthesis denotes that the man whose name it follows must pass a supplemental before clear standing is obtained.

THIRD YEAR

Civil Engineering

Honors

W. B. Beatty, B. S. Black, G. M. Cook, A. G. Gray, E. R. Gray, A. W. Hayman, R. L. Hearn, H. J. Heinonen, O. Holden, H. R. MacKenzie, K. F. Mickleborough, W. C. Murdie, J. E. Perron, J. E. Ritchie, L. Sewell, W. G. Ure, D. H. Weir.

Pass

C. R. Avery, F. W. Beatty (hydraulics), D. Blain, O. L. Cameron (theory of const. hydraulics), L. L. Campbell, G. M. Carrie (th. of const. hydraulics), W. G. Clark (photography), J. A. Coombs (method of least sqs. astr. and geod.), A. J. Dates, F. R. Fiddes (th. of const. ltd. cos.), D. H. Fleming (ast. and geod.), E. S. Fowlds, J. S. Galbraith, A. M. German (calculus. th. of const.), H. M. Goodman (th. of const.), J. R. Hamilton (th. of const. photography), H. A. Hawley, J. T. Howard (Eng. chem.), E. T. Ireson, G. R. Johnson (st. of mat'ls. lab., Eng. chem.), R. L. Junkin (meth. of l'st sqs.), J. S. Laing, N. Lawless (ast. and geod., Eng. chem.), T. V. McCarthy, W. L. McFaul, R. J. McKenzie (th. of const.), A. R. MacPherson (ast. and geod.), W. H. MacTacvish, N. C. Millman, T. R. Moore (asst. and geod.), F. J. Mulqueen (meth. of l'st sqs.), N. F. Parkinson (photography), J. J. Phillips (th. of const.), H. C. Quail (ast. and geod.), J. M. Riddell, C. S. Robertson (th. of const.), W. A. Spellman (Ltd. cos.), D. Sutherland (th. of const. photography), R. Tasker (ast. and geod., surveying), J. M. Thompson, C. F. vonGunten, W. S. Winters (French), R. F. B. Wood (ast. and geod., calculus).

Mining Engineering

Honors

R. E. Binns, R. W. Diamond, K. L. Newton, D. G. Sinclair, W. K. Thompson.

Pass

C. A. Bell, T. R. Buchanan, W. B. Caldwell (petrography, mining), R. T. Carlyle, H. Clark (mining), W. T. Curtis (th. of const. hydraulics), W. H. Garnham, A. C. McDougall (anal. chem., mining), D. A. S. Mutch, R. M. Trow (met. of gold).

Mechanical Engineering

Honors

A. S. Anderson, F. R. Simms.

Pass

B. H. A. Burrows, (elec., alt. current), R. M. Carmichael, B. D. Clegg, H. D. Davidson (th. of const. hydraulics), F. F. Foote,

A. J. Gray, R. A. Henry (alt. current), K. E. Shaw, R. E. Watts (th. of const., elec.), C. A. Webster.

Architecture

Honors

L. C. M. Baldwin, B. R. Coon, H. D. Livingstone, R. S. McConnell.

Pass

B. Brown (calculus photography), R. W. Soper, H. Webs er (th. of const.).

Analytical and Applied Chemistry

Honors

A. R. Bonham, L. W. Doncaster.

Pass

J. C. Huether, C. J. Otto (heat lab.).

Chemical Engineering

Honors

G. E. Clarkson.

Pass

K. S. McLaughlin, P. J. Relyea.

Electrical Engineering

Honors

R. J. Allen, L. R. Brereton, W. B. Buchanan, T. A. Hill, G. J. Mickler, E. G. Ratz, C. C. Rous, M. C. Sharp, J. M. Strathy, D. J. Thomson, J. A. H. Wigle.

Pass

R. S. Bell (elec. design), E. R. Bonter, J. H. Coleman, E. L Deitch, W. G. Duncan, J. P. Hadcock, H. C. Harris, T. F. Howlett (electro-chem.), S. S. Kelly, A. E. Kerr, C. E. Kilmer, (hydraulics, alt. current), A. Leslie, L. B. Lytle (elec. design, photography), H. A. MacKenzie (thermo. elec.), J. W. Peart, C. H. Russell (alt. cur., electro-chem.), A. A. Scarlett, T. E. Torrance (thermo., photography), H. E. Whitely, A. J. Wright, R. B. Young (alt. cur.).

SECOND YEAR

Civil Engineering

Honors

F. C. Adsett, J. L. Alton, E. L. Bedard, H. J. Bedard, M. de G. Boyd, D. H. Campbell, J. J. Campbell, W. Cuthbertson, R. D. Davidson, F. W. Douglas, H. E. Eyres, O. M. Falls, J. W. H. Ford, J. L. Foreman, J. J. Hanna, L. T. Hayman, B. B. Hogarth, H. O.

Leach, R. E. Lindsay, C. T. Lount, D. McCaw, R. C. McDonald, H. E. Macpherson, H. N. Macpherson, F. C. Mechin, J. R. Montague, E. P. Muntz, C. Noecker, A. H. Parker, R. G. Patterson, H. L. Sheppard, J. B. Skaith, C. N. Temes, F. T. Van Dyke.

Pass

J. T. Belcher, S. G. Bennett (surveying, hydrostatics), P. V. Binns, J. M. Blythe, J. H. W. Bower, R. M. Christie, W. W. Code (Eng. chem.), C. P. Cotton, (calculus, Eng. chem.), J. W. Crashely (spher, trig., org. chem.), G. F. Dalton, R. F. Davidson (org. chem., Eng. chem.), J. A. Elliott, (trig., calculus), G. O. Fleming (hydrostatics), C. H. R. Fuller, R. W. Gouinlock (astronomy, Eng. chem.), J. H. Hawes (hydrostatics), S. A. Hustwitt, R. P. Johnson (spher. trig.), J. Kay, N. G. Keefer (Eng. chem., mineralogy), J. A. Knight, C. A. Macdonald (sur., min.), J. A. P. Marshall, W. G. Millar, A. S. Millar (cal., hydrostatics), J. S. Mitchell, E. B. O'Connor (cal. min.) ,W. M. Omand (dyn., optics), J. A. Owens, C. W. Pennington (calculus), C. V. Perry, P. H. Raney (min.), R. H. Rice (spher. trig., sur.), H. M. Rowe (chem. lab.), F. S. Rutherford (dynamics), N. E. Sheppard (hydrostatics), S. Shupe (calculus, sur.), C. E. Sinclair (str. of materials, Eng. chem.), R. B. Sinclair (min. lab.), H. M. Smith (min. lab., org. chem.), N. L. Somers, R. A. Steven, I. R. Strome (min.), G. E. Treloar, H. O. Waddell, H. W. Wagner, H. D. M. Wallace, P. L. Whitely (min., banking and finance), H. P. Wilson (Eng. chem.), G. A. Wood.

Mining Engineering

Honors

W. A. Macdonald, J. G. Shepley, B. N. Simpson.

Pass

F. C. Andrews (inorg. chem., Eng. chem.), E. P. Cameron (min., geology), J. M. Carter, W. A. Delahaye, S. D. Ellis (chem. lab. quant.), J. S. Fleming, J. R. Gill, D. S. Halford (min. lab., surveying), W. Hutchings (min., geol.) S. A. Lang (calculus), H. J. MacKenzie (calculus), W. D. Powell (mineralogy), J. Ross (min.), lab., optics), C. M. Scarborough (trig.), G. M. Smyth (inorg. chem.), G. B. Taylor, J. S. Taylor (inorg. chem.), J. A. Tilston (trig., inorg. chem.), R. W. Young (calculus, Eng. chem.).

Mechanical Engineering

Honors

H. H. Brown, E. D. W. Courtice, G. H. Hally, H. S. Kerby, J. G. Scott.

Pass

H. M. Campbell, W. H. Hall (cal. Eng. chem.), B. MacKen, drick (steam engines, optics), F. H. Mason (steam engines, banking-finance), H. W. Maxwell, D. L. Munro (Eng. chem.), A. K. Purdy (cal., steam engines), E. H. Tennent (calculus), M. F. Verity (optics).

Architecture

Honors

W. C. Skinner, A. C. Wilson.

Pass

H. Heaton, E. E. H. Hugli (hydrostatics, hist. of arch.), J. M. Robertson (hydrostatics).

Analytical and Applied Chemistry

Honors

J. G. G. Frost.

Pass

J. E. Clark, A. J. Holden, O. G. Lye, W. E. Phillips.

Chemical Engineering

Honors

C. N. Candee.

Pass

W. E. Milligan, D. Morrison, A. W. Sime, E. A. Twidale, A. E. Wigle.

Electrical Engineering

Honors

H. M. Black, A. W. Crawford, H. F. Elliott, H. J. Franklin, A. S. Jannati, C. W. Latimer, W. E. Longworthy, A. M. Mackenzie, R. G. Mathews, P. H. Mills, L. O'Donnell, G. O. Philp, R. O. Standing, E. C. R. Stoneman, G. C. Story.

Pass

C. E. Armer, B. W. Bemrose (calculus, steam engines), A. L. Birrell (first year dynamics, hydrostatics), W. D. Brown, H. A. Campbell (calculus), H. C. Edwards (calculus), D. T. Flannery, E. I. Gill (electricity,) C. I. Grierson (Eng. chem), G. E. Griffiths (first year dynamics, trig.), R. C. James, C. M. Jones (calculus, electricity), J. I. Kammin (Eng. chem.), J. A. Kerr (chem. lab.), G. E. Kewin (steam engines), J. S. McIntyre (chem. lab.), D. L. McLaren, J. A. Marshall (org. chem.), E. T. Martin (steam engines), J. A. Nichols (calculus, theory of mech.), C. L. Nicholson (calculus), J. D. Peart, A. S. Robertson, H. D. Rothwell (first year French, calculus), W. E. Russell (str. of mat'ls, elec.), W. M. Ryan (accounts, calculus), A. G. Scott (des. geom.), F. M. Servos, W. S. Tull.

FIRST YEAR

Civil Engineering

Honors

L. Adlard, F. D. Austin, E. D. Brouse, W. G. Brown, L. R. Brown, F. M. Buchanan, G. A. Cockburn, R. M. Cockburn, N. H.

Daniel, W. L. Dickson, C. A. Doherty, A. C. Evans, W. G. French, R. D. Galbraith, E. R. Grange, J. E. Hanlon, C. E. Hogarth, C. W. H. Jackson, G. W. F. Johnson, R. E. Laidlaw, R. G. Lye, K. D. McDonald, D. F. McGugan, A. R. Mendizabel, G. Mitchell, J. T. Mogan, H. R. Nicklin, H. S. Nicklin, C. F. Porter, J. E. Porter, W. E. Brayley, A. A. Richardson, E. H. Scott, R. G. Scott, J. H. Shaw, J. A. Thom, J. H. Wallis, F. Weir, J. N. Williams, J. C. Wilson, H. A. Wood, J. A. Trebilcock.

Pass

A. C. Anderson (dynamics), F. A. Bartlet (trig.), H. R. Browne (trig., elem. chem.), L. Chavignaud (accounts), J. D. Cook (dyn.), A. B. Crealock, E. V. Deverall, W. L. Dobbin (elem. chem.), G. A. Downey, H. S. Falconer (dyn.), W. Fraser, L. F. Gaboury (trig., dyn.), G. A. Gooderham (trig.), G. S. Gray, M. Gurofsky (accounts), C. E. Hastings (dynamics, elem. chem.), C. Hayward (algebra, trig.), J. W. Hermon, (dyn., accounts), R. R. Hewson (dyn.), W. E. Irwin, E. H. Jupp (algebra), A. M. Little (French), W. E. Lockhart, E. V. McKague, J. McLaughlin (dyn., elem. chem.), G. D. Maxwell, B. M. Morris, (dyn. elem. chem.), M. A. Neilson (trig.), P. L. Pearce (dyn.), N. L. Powell, G. Rankin (dyn.), W. B. Redman, W. B. Scott (accounts), J. S. Sheehy, J. F. L. Simmons (dyn. accounts), R. M. Speirs (trig. dyn., F. S. Storms (elem. chem., accounts), G. S. Stratford (dyn., accounts), J. E. Tremayne (dyn., accounts), J. A. Vance, L. P. Vezina (algebra, elem., chem.), C. H. Wheelock, L. Withrow trig., dyn.).

Mining Engineering

Honors

F. M. D. Carmichael, E. R. Emmerson, J. S. Gitson, M. S. Hasa, W. T. Hall, L. T. Higgins, W. R. McCaffrey, I. M. Macdonell, S. Peterson, H. Stewart, J. B. Stitt, J. E. C. Stroud, W. S. Wilcock.

Pass

W. Allan (sur., accounts), M. R. Arthur, C. K. Macpherson (dyn.), L. F. Simpson, (anal. geom.), B. C. Tomlinson (accounts).

Mechanical Engineering

Honors

R. H. Lloyd, W. R. McGhie, J. C. Newcombe, A. N. Payne.

Pass

J. N. Cunningham (algebra, trig.), J. L. Delisle (trig., elem. chem.), J. Gray, W. S. Kidd, R. B. McBride, H. M. Peck, F. G. Reid, J. D. Relyea (trig., elec. and mag.), A. H. Smyth, H. C. Taylor (trig., dyn.), D. B. Webster (dyn.).

Architecture

Honors

K. C. Burness, M. Dennison, T. S. Graham, A. Morris, J. T. Rose.

Pass

H. J. Burden, R. W. Catto (algebra, accts.), J. J. Davidson (accts. bldg. meas'ts), G. R. Edwards (trig., elem. chem.), N. H. Korn (elem. chem., French), R. Tyrwhitt (trig., accts.), W. S. Wilson.

Analytical and Applied Chemistry

Honors

W. P. Brodie, S. Feather, F. F. Hicks, W. Uffelman.

Pass

N. B. Brown (elec. and mag.), H. Cole, G. G. Macdonald (trig., accts.), W. D. Morris, W. H. Stark (prac. min.), L. T. Watson (trig.).

Chemical Engineering

Honors

L. G. Glass, A. A. Swinnerton.

Pass

J. A. Breithaupt (accts.), H. Ramsay (trig.), A. M. Thomas.

Electrical Engineering

Honors

P. Bennett, C. J. Davey, J. Dibblee, R. V. Elliott, E. W. Ellis, W. J. Fulton, D. German, W. H. R. Gould, T. P. Ireland, A. G. Ironside, H. C. Karn, G. W. Lawrence, C. R. McCort, E. W. Savage, W. G. Shier, C. N. Simpson, C. A. Smith, W. A. Steel, A. N. Suhler, C. C. Rance, J. Richmond, J. D. Stone, A. L. Ward, F. M. Ward.

Pass

W. V. Ball, T. R. Banbury, V. A. Beacock (elem. chem.), W. H. Bonus (dyn., elec. and mag.), H. C. Budd, trig.), J. M. Carswell (elem. chem.), F. H. Chandler, W. W. Code (dyn.), G. P. Davidson, W. A. Dean (algebra, dyn.), C. W. Dobbin (trig.), A. Fleming (trig. dyn.), L. W. Harrow, S. J. Hubbert (algebra), J. A. Kennedy, J. E. McLarty (trig., French), A. H. Macfarlane, T. R. Manning, W. H. Metz, W. R. Meyer (elem. chem.), C. W. Mollard, E. M. Monteith (elem. chem. French), W. B. Patterson (algebra, dyn), W. F. P. Purdy (elec., and mag.), N. F. Seymour (elem. chem.), J. L. Skinner (trig., elec. and mag.), A. G. Smith (elec. and mag.), A. N. Taylor (algebra, trig.), A. S. Robertson, W. F. Rosar (dyn., elec., and mag.), A. C. Ross (algebra), S. M. Wedgwood, A. E. Widdicombe, F. C. Wilson (dyn., elem. chem.).

SUPPLEMENTAL EXAMINATIONS

Passed

J. H. W. Bower (trig.), F. J. Cannon (elem. chem.), G. F. Dalton (trig.), J. A. Elliott (algebra), J. H. Hawes (trig.), W. G.

Millar (trig.), J. A. Owens (elem. chem.), F. S. Rutherford (trig.), N. E. Sheppard (trig.), R. A. Steven (trig.), P. L. Stevens (trig.), I. R. Strome (elem. chem.), P. L. Whiteley (trig.), E. O. Wood (chem. elem.), B. Walton (anal. geom.), J. R. McIntosh (trig. surveying), H. R. Hopkins (anal. geom., trig.), W. E. Longworth, (trig.), J. S. McIntyre (dynamics, trig.), E. T. Martin (accts., algebra), J. A. Nichols (algebra, trig.), H. D. Rothwell (trig.), G. R. Mansell (algebra), J. S. Taylor (trig.), F. H. Mason (elec. and mag., dynamics), E. M. Abandana (surveying), O. L. Cameron (calculus, French), L. L. Campbell (hydrostatics), G. M. Carrie (calculus), J. C. Christner (astronomy), J. A. Coombs (optical lab.), A. M. German (French), J. R. Hamilton (calculus), J. T. Howard (prac. min.), G. R. Johnson (astronomy, optical lab.), R. L. Junkin (surveying), J. S. Laing (calculus), R. J. McKenzie (calculus), A. R. MacPherson (calculus), T. R. Moore (prac. min.), J. J. Phillips (calculus, banking and finance), C. S. Robertson (prac. min.), R. F. B. Wood (French), G. L. Berkeley (prac. ast. and geod.), A. W. Pearson (elec.), L. Eadie (elec., retaining walls), K. E. Shaw (hydrostatics), J. H. Curzon (econ. geol.), J. H. Coleman (calculus), J. P. Hadcock (calculus, th. of mechanism), C. E. Kilmer (prac. chem.), T. R. Buchanan (calculus, mineralogy), H. Clark (optical lab.), A. C. McDougall (geology), A. R. Bonham (min. lab.), J. C. Huether (phys. chem., optics), L. A. Badgley (surveying), R. G. Sneath (asst. and geol.), W. G. Worden (sur., hydraulics), M. B. Heebner (anal. chem., thermo.), A. J. McLaren (min. lab.), E. A. McPherson (elec.), W. H. Wylie (th. of const.), C. H. Eckert (min. lab.), E. A. Greene (elec. design), M. H. Murphy (least sqs. elec.), B. W. Pick (thermo., th. of const.), R. D. Torrance (ast. and geod.), W. G. Tough (ast., and geod.), W. D. Walcott (surveying) H. Goodridge (ast. and geod.), O. H. Hoover (th. of const.), F. M. Macdonald (th. of const.), J. B. Ferguson (st. of materials).

To Be Taken

F. J. Cannon (dynamics), P. L. Fancher (dynamics), D. B. Gardner (dynamics), P. L. Stevens (dynamics), L. B. Tillson (anal. geom.), H. Raymond (trig.), B. Walton (trig.), K. A. Jefferson (anal. geom.), S. M. Richardson (algebra, trig.), G. W. Rutter Algebra), P. G. C. Campbell (dynamics), R. D. Jones (dynamics), algebra), F. L. Mills (algebra), F. W. Hutcheson (algebra, trig.), J. H. Curzon (thermo.), E. M. Abendana (astornomy), J. C. Christner (French).

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